SEPTEMBER 1961
Volume 199 Part 1

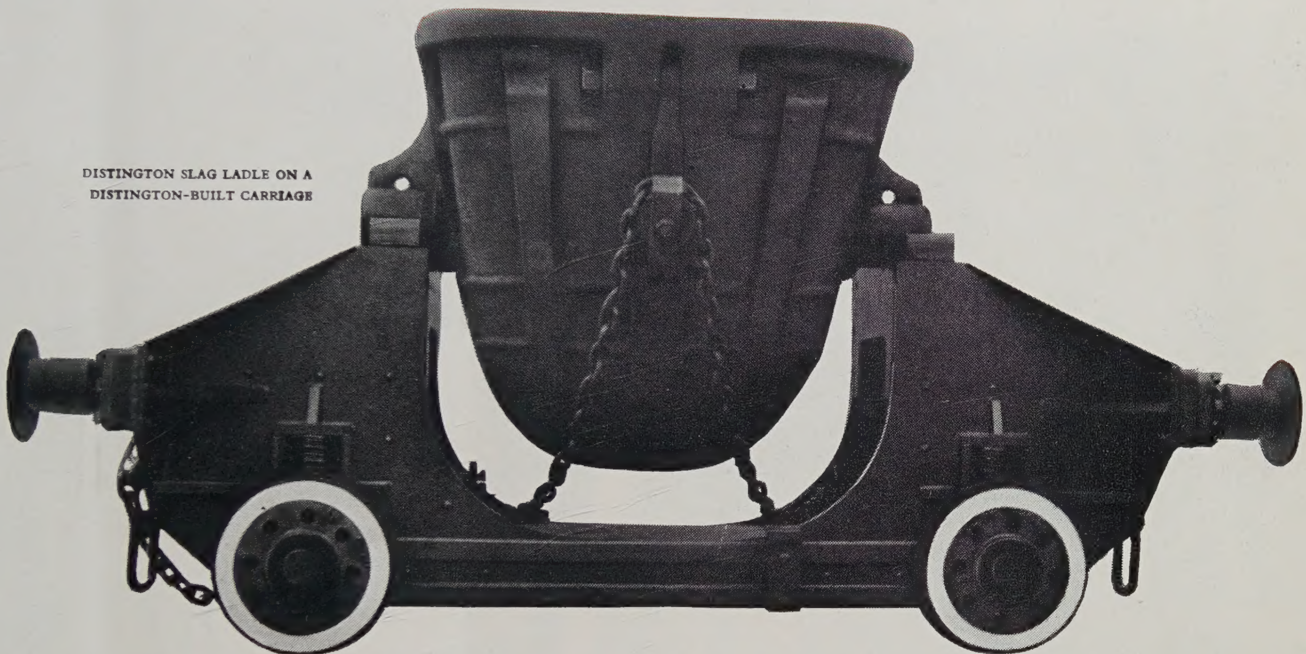
Established 1869
Incorporated by Royal Charter 1899

A full list of contents is given on the Title Page (see page 69 of the Advertisement Section)

JOURNAL OF THE IRON AND STEEL INSTITUTE

PRICE TWENTY-FIVE SHILLINGS

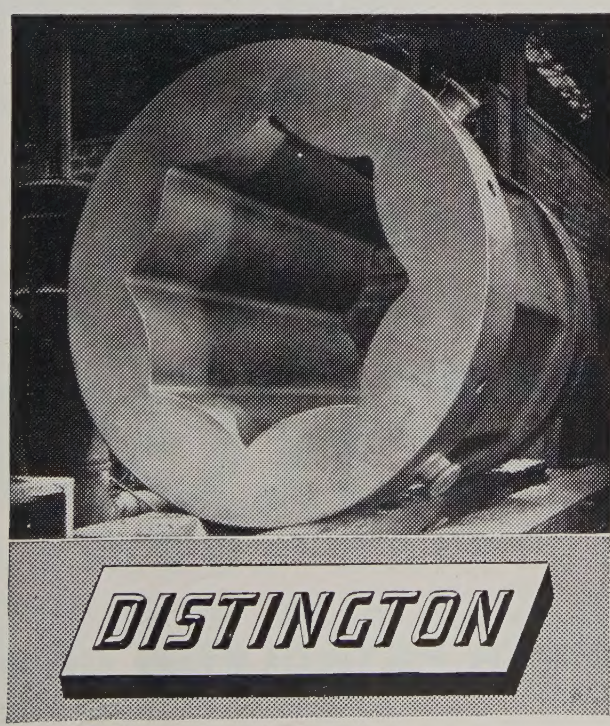
INGOT MOULDS SLAG LADLES STEELWORKS PLANT AND EQUIPMENT



DISTINGTON SLAG LADLE ON A DISTINGTON-BUILT CARRIAGE

are supplied by Distington Engineering Company Limited to many steelworks. The Distington's foundry has the highest output of any ingot mould foundry in Europe, and specialises in producing ingot moulds, bottom plates and slag ladles. It can handle castings up to 120 tons in weight.

OCTAGONAL FORGING INGOT MOULD



DISTINGTON ENGINEERING COMPANY LIMITED

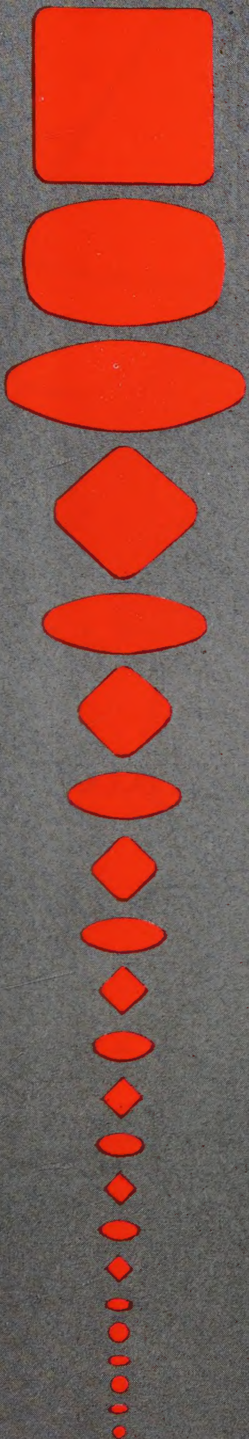
WORKINGTON, CUMBERLAND

A subsidiary of
The United Steel Companies Limited

CA.20

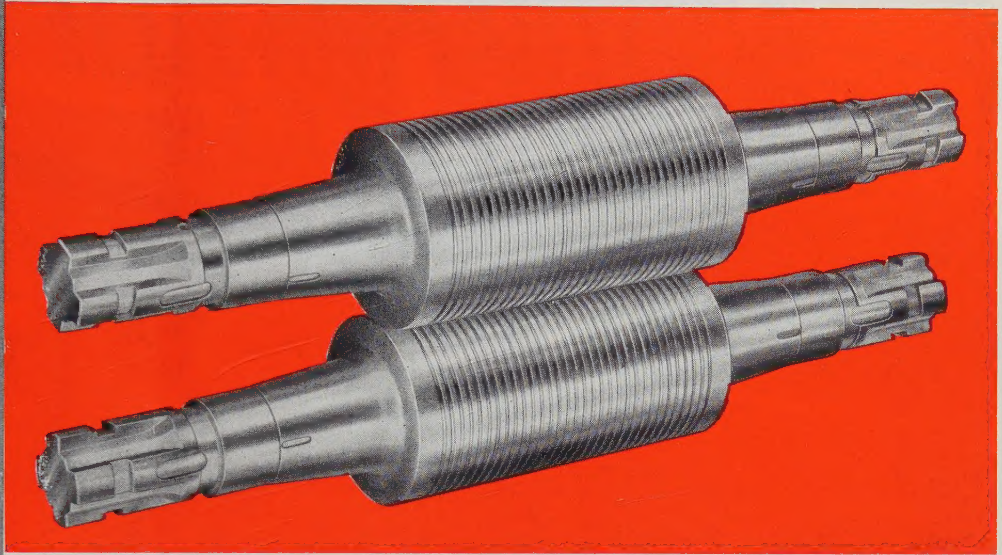

Experience
proves
it!
Results
confirm
it!


We're certainly getting
good performance
from this
furnace...
since we changed to
PICKFORD HOLLAND
REFRACTORY BRICKS
PICKFORD, HOLLAND & CO. LTD · SHEFFIELD · TELEPHONE: 33921



ÅKERS ROLLS

for Modern Small Section and Wire Rod Mills



Spheroidal Graphite Rolls are ideal for the deep grooves and the heavy reductions—withstand heavy strains and show little wear.

Clear Chill Rolls with tough core and hard even chilled surface, free from pores, ensure reliability of maximum output and products of perfect surface finish and precision.

Recommended qualities

Roughing train:	Spheroidal Graphite Rolls		
		SG-Ac	300—450 Brinell
		SG-P	300—450 Brinell
	Clear Chill Rolls		
		CC-P-Mo	about 450 Brinell
		CC-P	about 450 Brinell
Intermediate train:	Spheroidal Graphite Rolls		
		SG-Ac	450—500 Brinell
	Clear Chill Rolls		
		CC-P-Mo	450—470 Brinell
		CC-P	450—470 Brinell
Finishing train:	Clear Chill Rolls		
		CC-P-Ni	about 550 Brinell

Top Quality Rolls from Åkers

AB ÅKERS STYCKEBRUK

SWEDEN

Postal address: Åkers Styckebruk

Sole agent for Great Britain:

Industrial & Metallurgical Equipment Ltd.

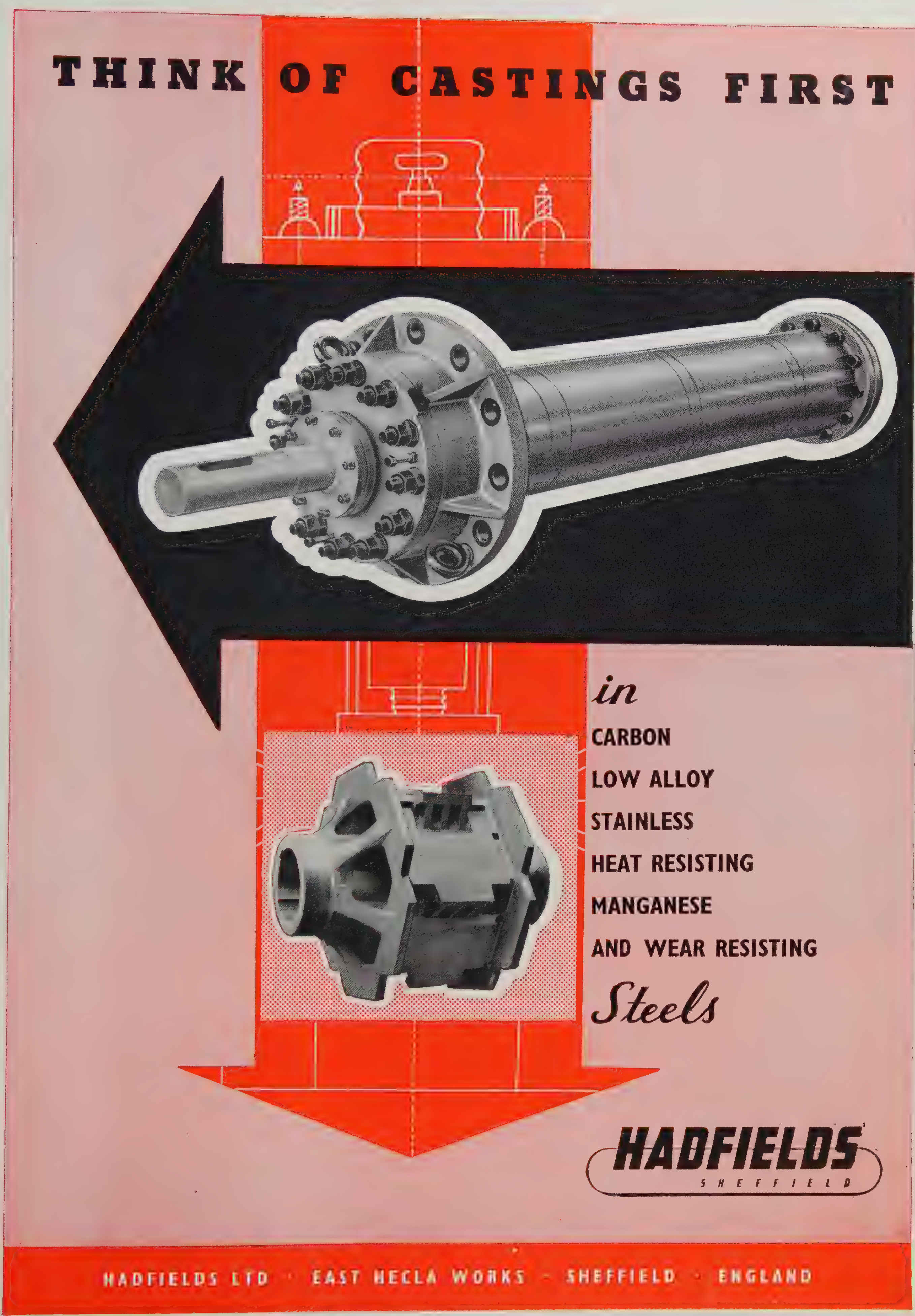
76 Cannon Street, London E.C.4

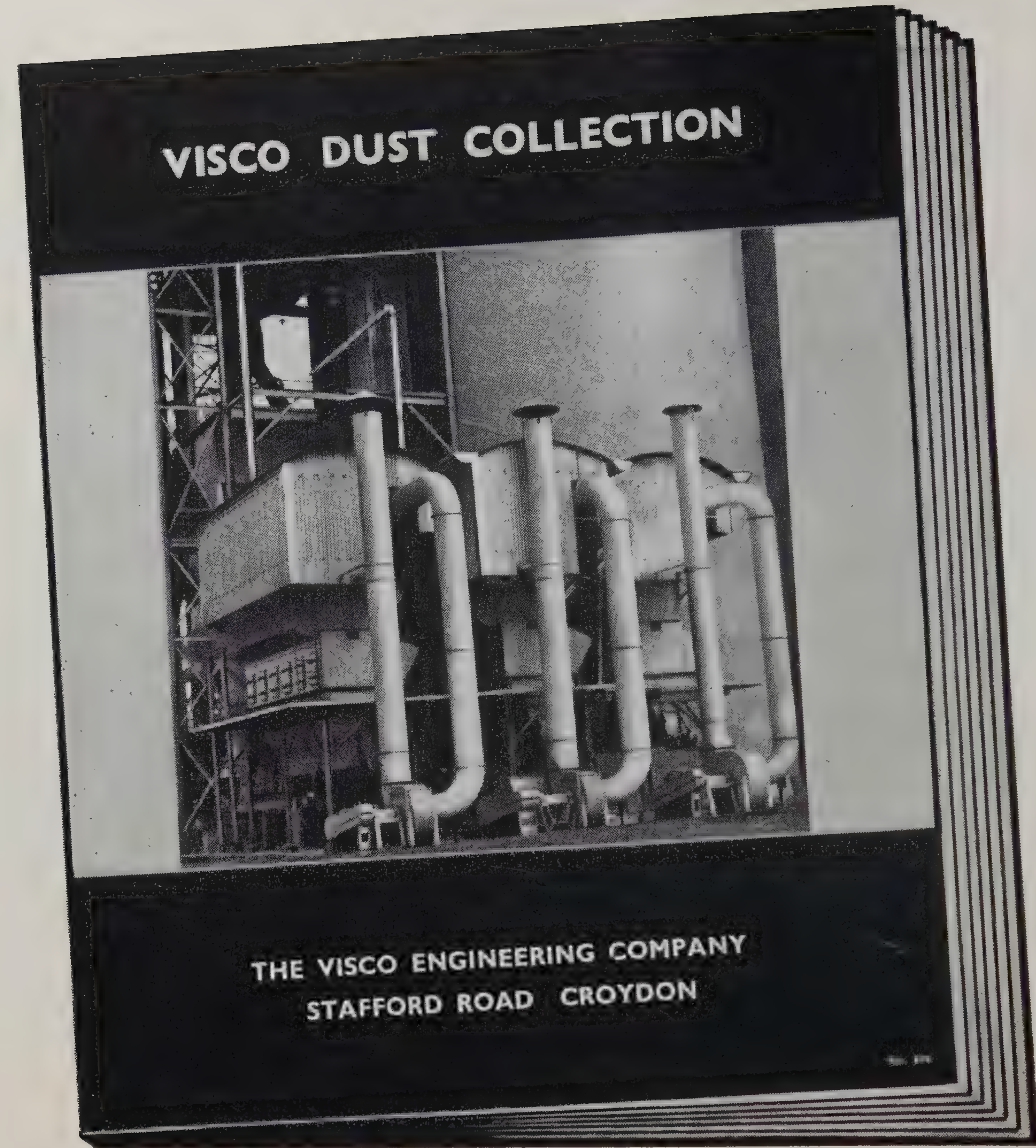
Tel: City 7072 Cable address: Indumel, London.

QUICK ROD REPLACEMENT

Deck replacement can be quickly completed by unskilled labour using the simple tools supplied. No bolts are used and deck sections can be mounted or disengaged in a few minutes.

A 6′ x 12′ Ty-rock rod deck screen undergoing tests with Labrador 'B' ore at Derby Works.


THINK OF CASTINGS FIRST
in
CARBON
LOW ALLOY
STAINLESS
HEAT RESISTING
MANGANESE
AND WEAR RESISTING
Steels
HADFIELDS
SHEFFIELD
HADFIELDS LTD · EAST HECLA WORKS · SHEFFIELD · ENGLAND



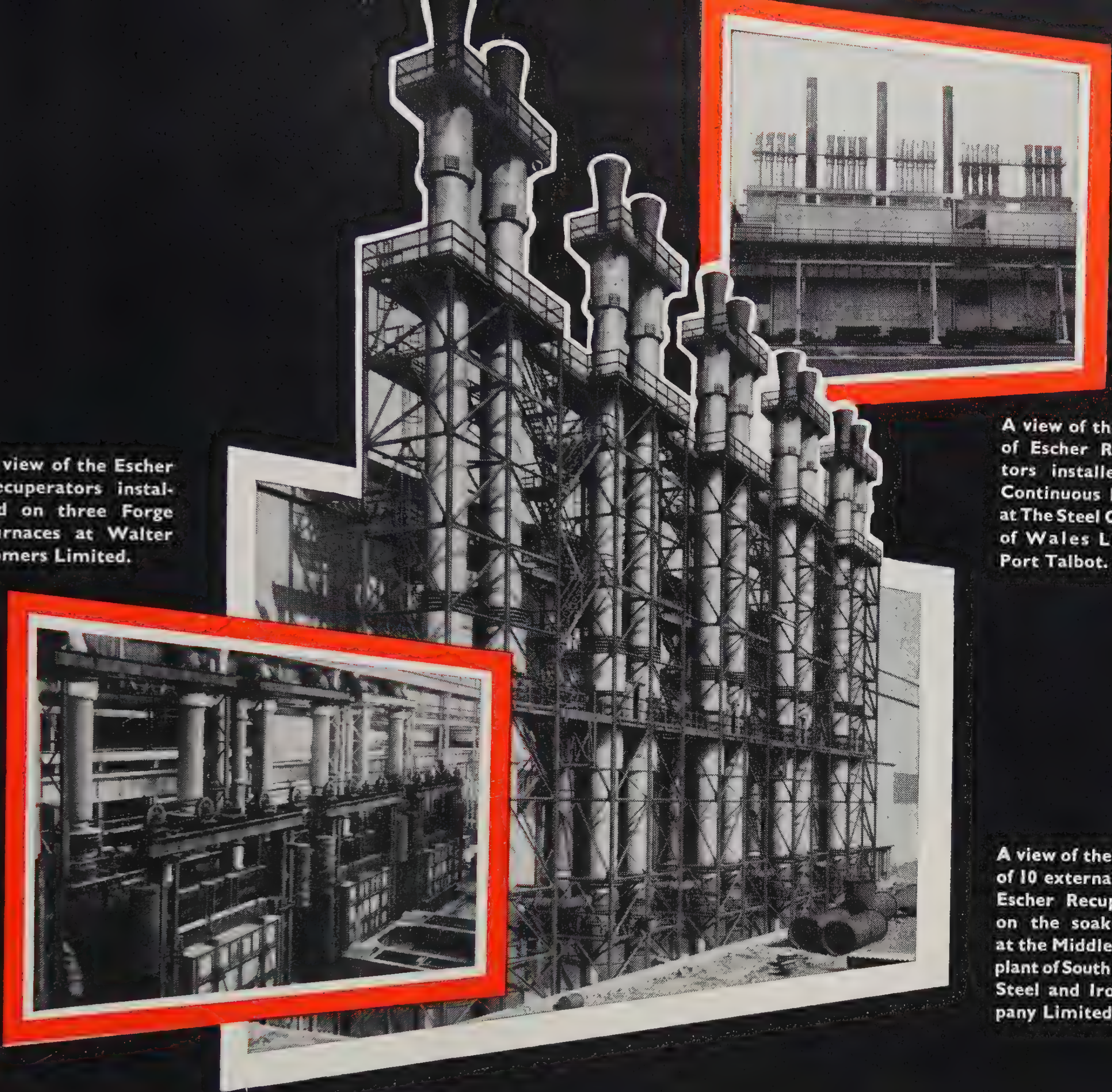
A new booklet on Dust Control

If you have a dust recovery and powder handling problem, you will find our latest brochure useful and interesting. In it we discuss dust collection in general and give numerous examples of the application of our dust recovery equipment. The information in the brochure is based on many years' experience in dealing with practically every kind of material in powder or fibrous form. It also contains illustrations showing different types of equipment varying from large centralized plant to small individual units. Brochure available on request to VISCO LIMITED, Stafford Road, CROYDON. Telephone Croydon 4181.

For Modern Dust Collection

VISCO

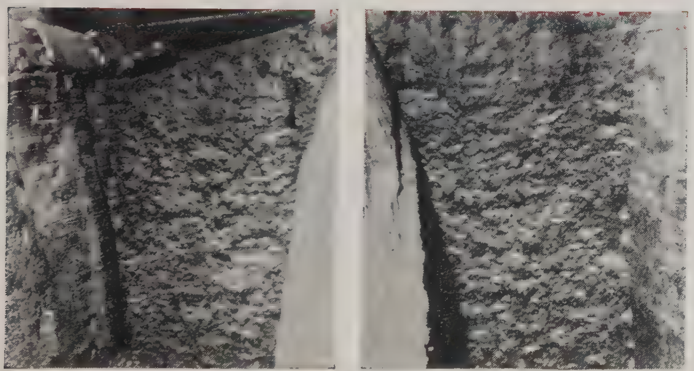
FWS



...Yes, through three campaigns

STEIN 70 IN OPEN HEARTH FURNACE ENDS

has given us best results ever



The photographs above (by courtesy of Messrs. Dorman Long (Steel) Limited, Acklam Works) show Stein 70 in the end walls, including the target area, at the conclusion of two campaigns totalling $21\frac{1}{4}$ weeks—41,869 tons Steel output. Final figures obtained were three campaigns with a total Steel output of 64,080 tons.

In rigorous trials Stein 70 used in the end and side walls of uptakes below stage level, has resulted in . . .

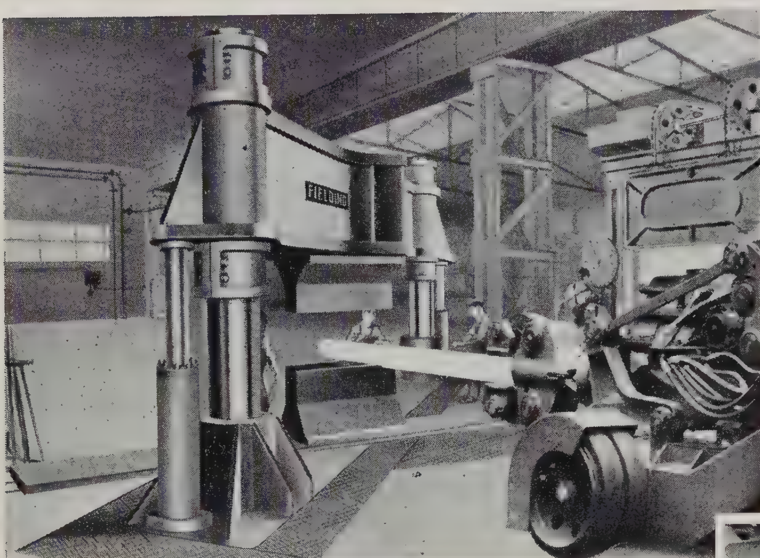
* **Longer Service Life**
* **Savings in Refractory Costs**

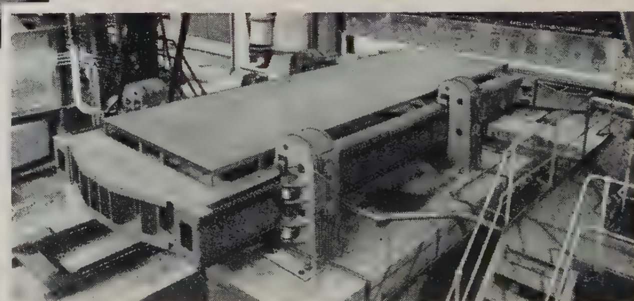
A detailed report of the trials in Great Britain and Overseas and the results achieved entitled "Stein 70 in Open Hearth Furnace Ends" will be sent to you on request.

STEIN *Refractories*

Proved in the service of industry for over 70 years

JOHN G. STEIN & CO. LTD. Bonnybridge, Scotland. Tel: Banknock 255 (4 lines) 361 & 362





STELVETITE— plastic bonded to steel has put a new face on L.D.E.P. CONTROL UNITS

Asked to make this control unit for a new production line, Lancashire Dynamo Electronic Products Ltd., leaders in the field of industrial control equipment, found they were able to imprint instructions on the vinyl by the Masseeley process. Previously they had fitted separate instruction panels after the units had been made.

Because Stelvetite eliminates this, together with need for surface finishing, and can be worked like ordinary sheet steel, L.D.E.P. have decided to use it extensively instead of stove-painted panelling.

This is saving the company production costs and time, in addition to making their units resistant to the difficult corrosive atmospheres encountered in industry.

Stelvetite

Plastic bonded to Steel

** Accepted by the Council of Industrial Design for "Design Index*

All enquiries about the L.D.E.P. Control Unit should be addressed to Lancashire Dynamo Electronic Products Ltd., Rugeley, Staffs.

*STELVETITE—made in co-operation with BX Plastics Ltd. by

JOHN SUMMERS & SONS LTD

Write to us at Dept. JS · Shotton · Chester · for full information


recent world-wide contracts include :
BEHIND
-:-durgapur blast furnace plant £6,500,000 :-
-:-:-:-ebbw Vale electrolytic tinning plan
-:-:-poland hot dip tinning line £180,00
aviles blast furnace and sinter plant £6,000,00
STOCKTON-ON-TEES · LONDON · JOHANNESBURG · SYDNEY · CALCUTT

When they talk about TEAM-WORK—

think of R·T·B

Two great teams—one at Richard Thomas, the other at Baldwins—united to form R T B.

Between them they have pioneered practically all the great advances in the industry—the manufacture of tinplate by various methods, the continuous-strip mill, and many other important developments.

It is this united teamwork that maintains the quality for which R T B have become famous.

The artist's design serves as a reminder of the coiled steel typical of the strip mill; tinplates, a lead-coated corrosion-resistant sheet, and the electrical laminations

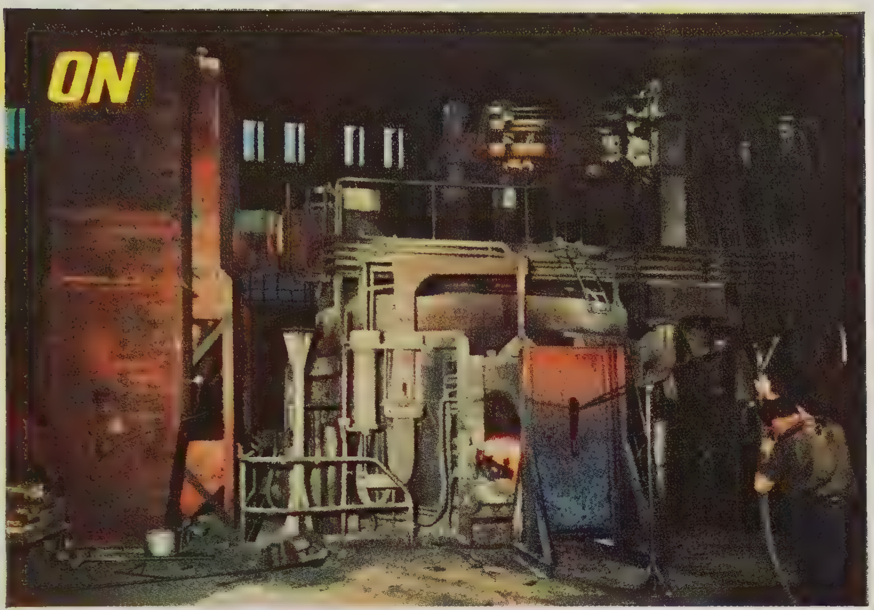
Richard Thomas & Baldwins Ltd.

R·T·B

DIRECT FUME EXTRACTION

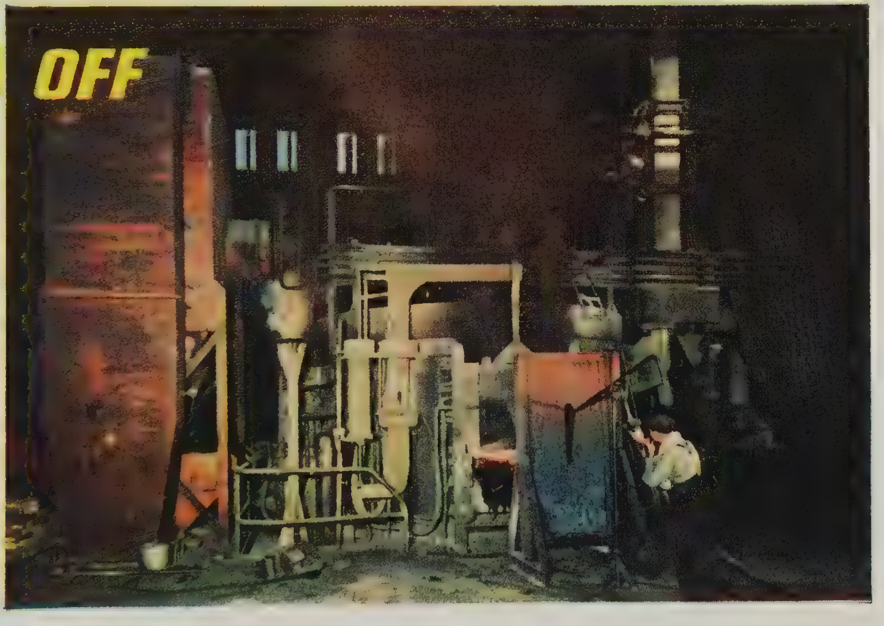
from electric arc furnaces

EXTRACTION SYSTEM



These photographs show the direct extraction system on a 40-ton electric arc furnace at Brymbo Steel Works (Branch of the G.K.N. Steel Company Limited). The complete absence of fume at the furnace when the system is in operation is clearly shown.

EXTRACTION SYSTEM



OTHER ORDERS INCLUDE

STEEL PEECH & TOZER

Direct fume extraction from two 110-ton furnaces—including gas cleaning plant.

THOS. FIRTH & JOHN BROWN LTD

Direct fume extraction from a 40-ton furnace—including gas cleaning plant.

BARROW STEELWORKS LTD

Direct fume extraction from a 20/25-ton furnace.

W. C. HOLMES & CO. LTD.

Gas Cleaning Division
Turnbridge, Huddersfield.

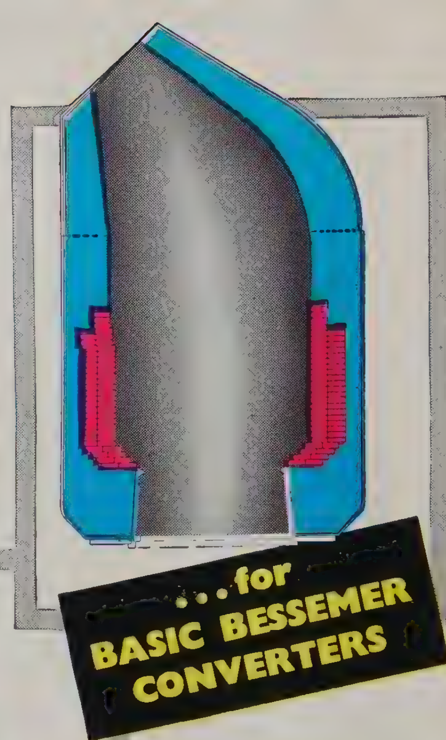
Tel: Huddersfield 5280 London: Victoria 9971
Birmingham: Midland 6830

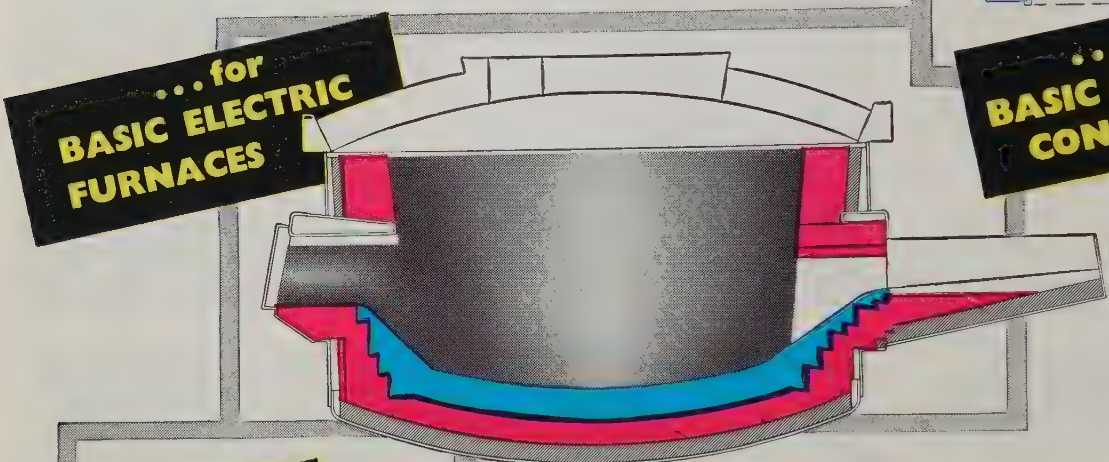
A Member of the B.H.D. Engineers Limited Group of Companies.

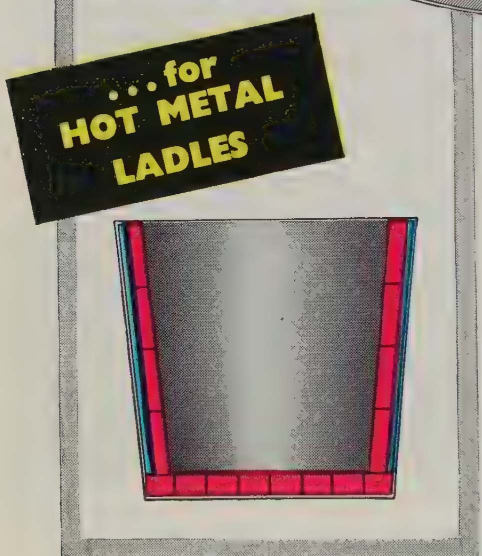
C266

GR '341'

Dolomite Bricks







'341' DOLOMITE BRICKS	(red)
RAMMED DOLOMITE	(blue)
GLENBOIG FIREBRICKS	(hatched)

'341' DOLOMITE bricks are manufactured from a dolomitic limestone which in the natural state approaches in chemical composition the mineral dolomite $CaCO_3$. M_3CO_3. The raw dolomite is dead-burned at high temperatures and it is then formed into suitable shapes by a new and unique brick-making process. Tunnel kiln firing at high temperatures produces a dense, volume stable and truly basic refractory of exceptional quality.
'341' DOLOMITE bricks are resistant to hydration and they can be transported and stocked in the same way as other basic bricks.
'341' DOLOMITE bricks are manufactured in various sizes designed to suit many applications.

TYPICAL CHEMICAL ANALYSIS

SiO_2	TiO_2	Fe_2O_3	MnO	Al_2O_3	CaO	MgO
2/3%	0.2%	1/2%	0.1%	1/2%	48/50%	36/40%

TYPICAL PHYSICAL PROPERTIES

TRUE POROSITY %	18/20
BULK DENSITY grams per c.c.	2.70/2.75
SPECIFIC GRAVITY	3.35
SPECIFIC HEAT	0.25
PERMEABILITY c.g.s. units	0.05
COLD CRUSHING STRENGTH p.s.i.	+ 8,500
Kilos sq.cm.	+ 600

SPALLING INDEX (small prism test)	Cycles + 30
PERMANENT LINEAR CHANGE 2 hrs. at 1,500°C.	Nil to 0.2%
WEIGHT PER CUBIC FOOT	175 lbs.
WEIGHT PER CUBIC METRE	2,700 kilos.
WEIGHT PER 1,000 BRICKS 9" x 4½" x 3" approx.	11,700 lbs.
,,	5,300 kilos.

'341' Dolomite bricks have proved to be the most economic basic bricks. These fired, volume stable products are superior to rammed or green dolomite blocks in Basic Bessemer converters, basic electric furnaces and ladles.

Please contact our Technical Service Department for further particulars of these and other applications for G.R. '341' bricks.

GENERAL REFRACTORIES LTD

GENEFAX HOUSE • SHEFFIELD 10 • Telephone: SHEFFIELD 31113

The GENEFAX GROUP for Everything in Refractories

LIGHT

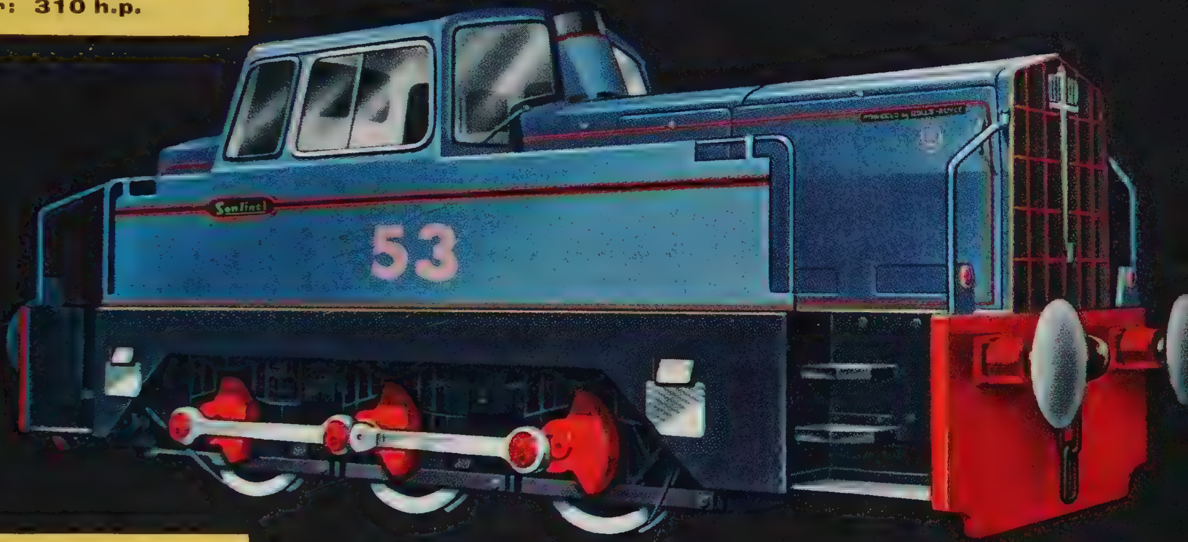
Weight: 34 tons
Drive: Chain
Horsepower: 230 h.p.

HEAVY

Weight: 40 tons
Drive: Side rods
Horsepower: 310 h.p.

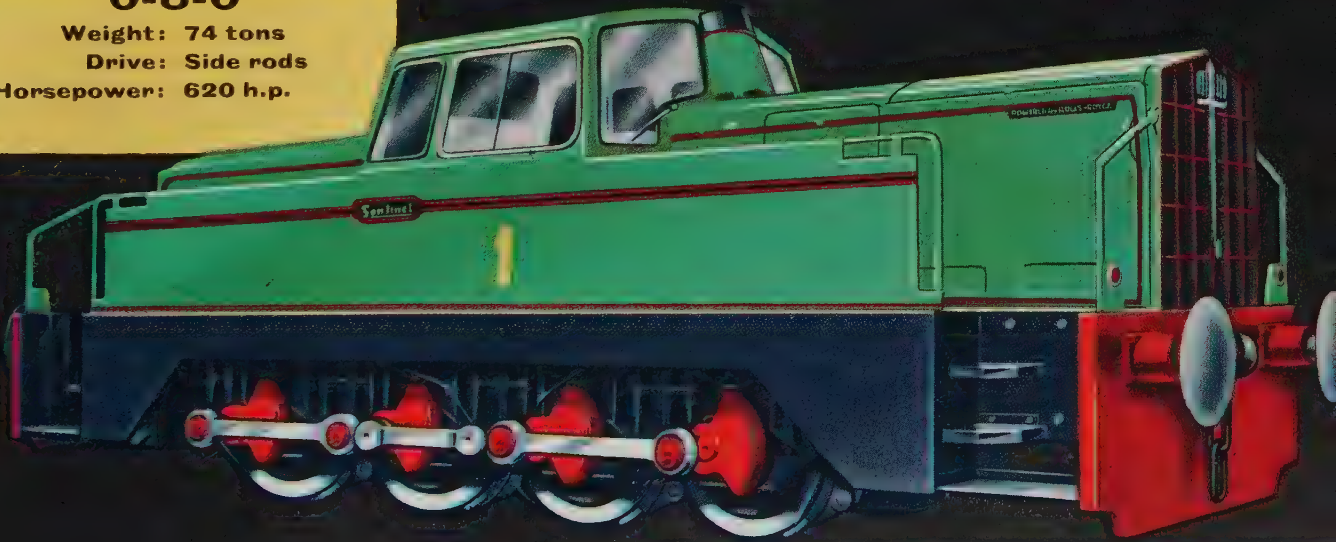
0-6-0

Weight: 48 tons
Drive: Side rods
Horsepower: 310 h.p.



0-8-0

Weight: 74 tons
Drive: Side rods
Horsepower: 620 h.p.



STANDARD GAUGE 4' 8½" ALL OTHER GAUGES WILL BE AVAILABLE IN DUE COURSE

Sentinel
LOCOMOTIVE

Sentinel

0-4-0 Light

STANDARD SPECIFICATION TYPE DL 100

General data

Weight (running order) — 34 tons
Tractive effort (maximum) — 22,000 lb.
Engine — Rolls-Royce Diesel C6SFL
Rating at 1800 r.p.m. — 229 B.H.P. gross
Torque Converter — Rolls-Royce CF 11500—fitted with twin plate over-centre clutch
Stall Torque ratio — 5.3 : 1
Maximum continuous speed — 16.6 m.p.h.
Reduction and Reverse Gearbox — Ratio 8.47 : 1 — Self-Changing Gears Limited
Final Drive 1.238 : 1 — $2\frac{1}{2}$″ pitch, A.S.A. Duplex Roller Chains
Overall reduction — 10.45 : 1
Gauge — 4′ $8\frac{1}{2}$″
Rail clearance (minimum) — 8″
Overall length — 23′ $10\frac{1}{2}$″ or 24′ $4\frac{3}{4}$″ according to buffer type

Overall width — 8′ 0″
Length over buffer beams — 21′ 3″
Height over cab — 10′ 4″
Wheelbase — 6′ 6″
Wheel arrangement — 0-4-0
Wheel diameter — 38″
Controls — Dual
Axle Boxes — Plain Bearings, White-metalled
Couplings — B.R. Standard
Buffers — Spring Buffers with 24″ diameter head
Fuel Tank capacity — 203 gallons
Brake Equipment — Laycock-Knorr Straight Air Brake. Engine-mounted Compressor belt-drive 15 cu. ft./mi

0-4-0 Heavy

STANDARD SPECIFICATION TYPE DL 200

General data

Weight (running order) — 40 tons
Tractive effort (maximum) — 25,300 lb
Engine — Rolls-Royce type C8SFL
Rating at 1800 r.p.m. — 311 B.H.P. gross
Torque Converter — Rolls-Royce type CF 11500 Ms 300 fitted with twin-plate over-centre clutch
Stall torque ratio — 5.2 : 1
Maximum continuous speed — 21 m.p.h.
Reduction & Reverse Gearbox — Self-Changing Gears Ltd. Ratio 10.23 : 1
Final drive — Coupling Rods
Overall reduction — 10.23 : 1
Gauge — 4′ $8\frac{1}{2}$″
Rail clearance (minimum) — 8″
Overall length — 24′ $4\frac{3}{4}$″ ('Wota' Buffers)
Overall width — 8′ 6″

Length over Buffer Beams — 21′ 3″
Height over Cab — 10′ 6″
Wheelbase — 6′ 0″
Wheel arrangement — 0-4-0
Wheel diameter — 42″
Controls — Dual
Axle Boxes — Timken Roller
Couplings — B.R. Standard
Buffers — 'Wota' 24″ diameter
Fuel Tank capacity — 227 gallons
Brake Equipment — Laycock-Knorr Straight Air Brake. Engine-mounted Compressor belt-drive 15 cu. ft./mi

0-6-0

STANDARD SPECIFICATION TYPE DL 300

General data

Weight (running order) — 48 tons
Tractive effort (maximum) — 28,800 lb.
Engine — Rolls-Royce C8SFL Diesel
Rating at 1800 r.p.m. — 311 B.H.P. gross
Torque Converter — Rolls-Royce type CF 11500 Ms 300 fitted with twin-plate over-centre clutch
Stall torque ratio (converter) — 5.2 : 1
Maximum and minimum continuous speeds — 18.4 m.p.h. to 0.9 m.p.h.
Reduction and reverse gearbox — Sentinel/Self-Changing Gears—reduction ratio 11.64 : 1
Final drive — Coupling rods
Overall reduction — 11.64 : 1
Gauge — 4′ $8\frac{1}{2}$″
Rail clearance (minimum) — 8″
Overall length — 27′ $0\frac{1}{4}$″ ('Wota' Buffers)

Overall width — 8′ 6″
Length over buffer beams — 23′ $10\frac{1}{2}$″
Height over cab — 10′ 6″
Wheelbase — 9′ 8″
Wheel arrangement — 0-6-0
Wheel diameter — 42″
Controls — Dual
Axle Boxes — Timken Roller
Couplings — As required
Buffers — 'Wota' 24″ diameter
Fuel Tank capacity — 227 Imperial gallons
Brake equipment – Sentinel/Laycock-Knorr Straig Air Brake. Engine-mounted 15 cu. ft. per minu belt-driven air compress

0-8-0

STANDARD SPECIFICATION TYPE DL 400

General data

Locomotive performance curve — TCM 10,092 LP 193
Weight (running order) — 74 tons (maximum)
Tractive effort (maximum) — 46,600 lb.
Final drive gearbox ratio — 9.40 : 1
Engines — Two Rolls-Royce type C8SFL
Rating at 1800 r.p.m. — 311 B.H.P. gross (283 B.H.P. nett) each at 1800 r.p.m.
Torque Converters – Two Rolls-Royce type CF11500 Ms 300 fitted with twin-plate over-centre clutch
Stall torque ratio — 5.2 : 1
Maximum continuous speed — 21 m.p.h. at most normal ambient temperatures for British Isles. In exceptional temperatures and with fouled radiator this might be reduced by 1 or 2 m.p.h.
Reduction and reverse gearboxes — 2-Self-Changing Gears Limited Type RF 11—ratio 9.40 : 1
Final Drive — Coupling Rods
Gauge — 4′ $8\frac{1}{2}$″

Rail clearance — 8″
Overall length — 32′ $4\frac{3}{4}$″ Turton 24″ wide buffers
Overall width — 8′ 6″
Length over buffer beams — 29′ 3″
Height over cab — 11′ $5\frac{1}{2}$″
Wheelbase — 11′ $10\frac{1}{2}$″
Wheel arrangement — 0-8-0
Wheel diameter — 42″
Controls — Dual (pneumatic)
Axle boxes — Timken Roller Bearing
Couplings — B.R. Standard Loose 3 Link
Buffers — Turton 24″ diameter (spring)
Fuel Tank capacity — 500 gallons maximum capacity if requir
Brake Equipment — Laycock-Knorr Straight Air brake. Engine-mounted compressors belt-driv 30 cu. ft./min. to

all Sentinel diesel locomotives are powered b

ocomotives

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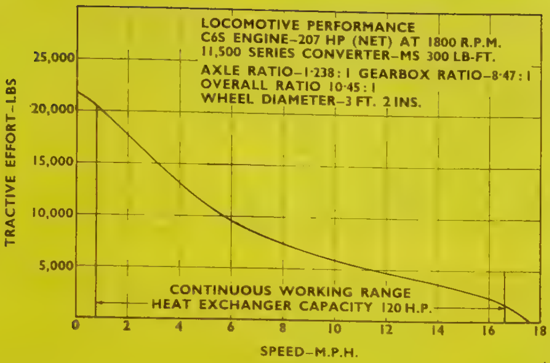

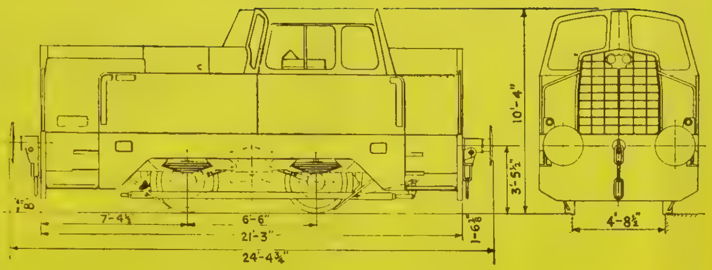

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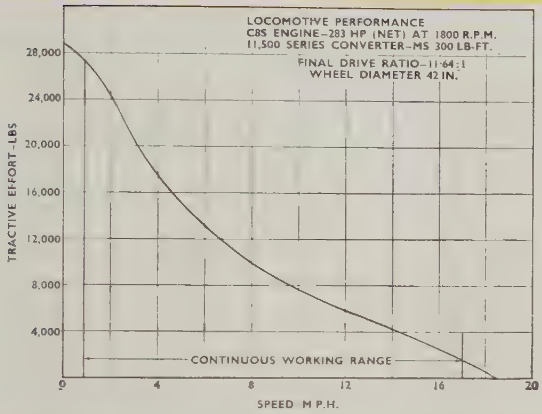

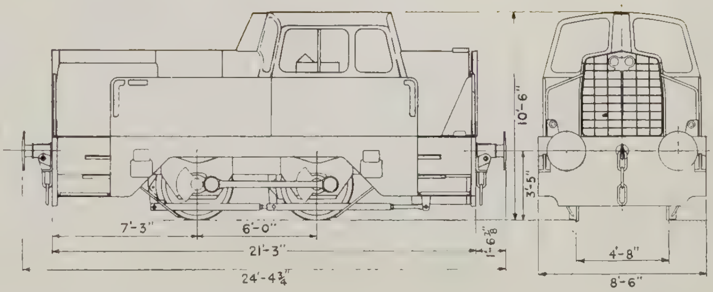

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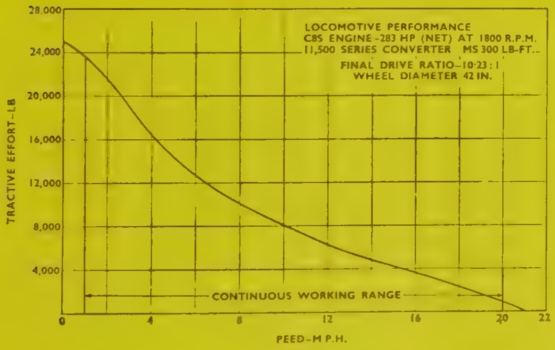

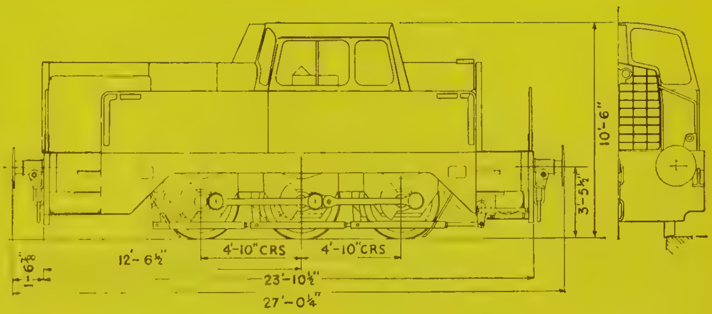

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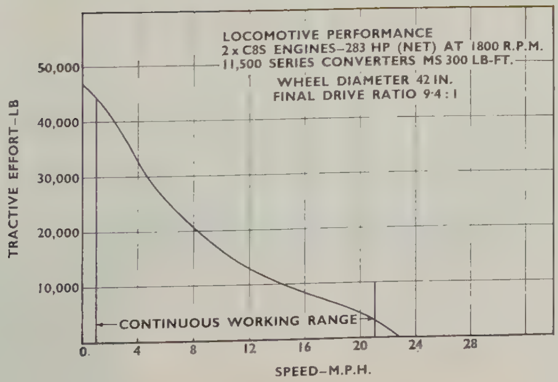
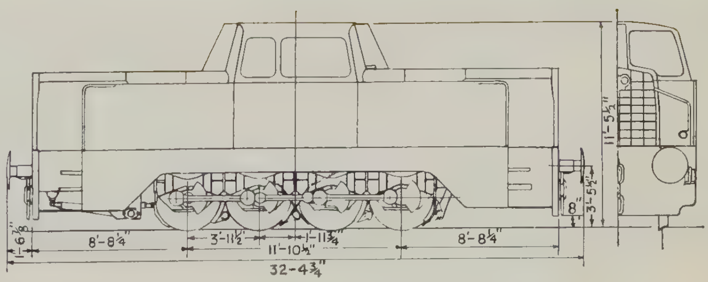
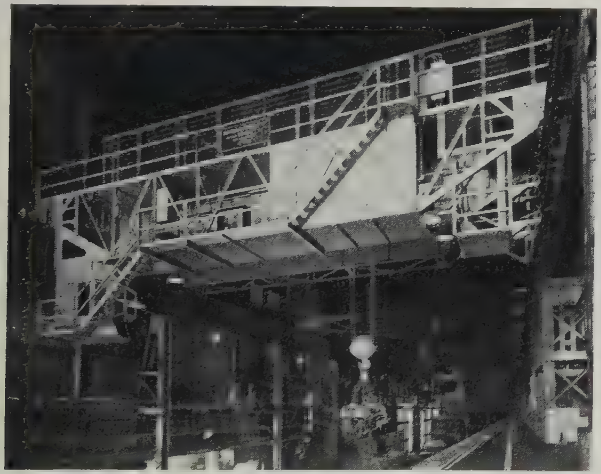
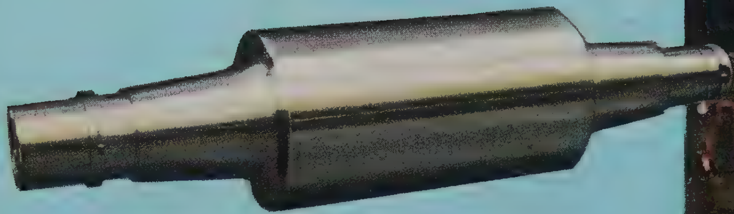




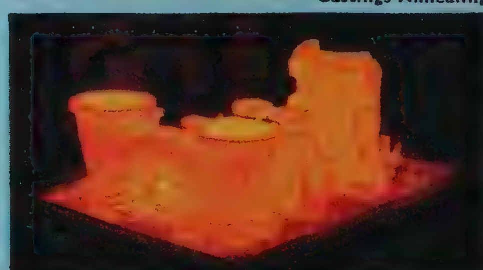
olls-Royce engines and torque convertors (TWIN DISC LICENCE)





Back-up Roll

Castings Annealing



Work Rolls

The heat-shock resistance of Vitreosil ensures accurate thermo-couple temperature readings without the slightest risk of contamination in molten steel. The cost of Vitreosil Dipping Tubes, from a few pence each, is negligible in relation to the loss incurred in a sub-standard casting. Full list of sizes and prices on request.

A BRITISH PRODUCT SERVING STEEL

all BRITISH TSL ...the BEST

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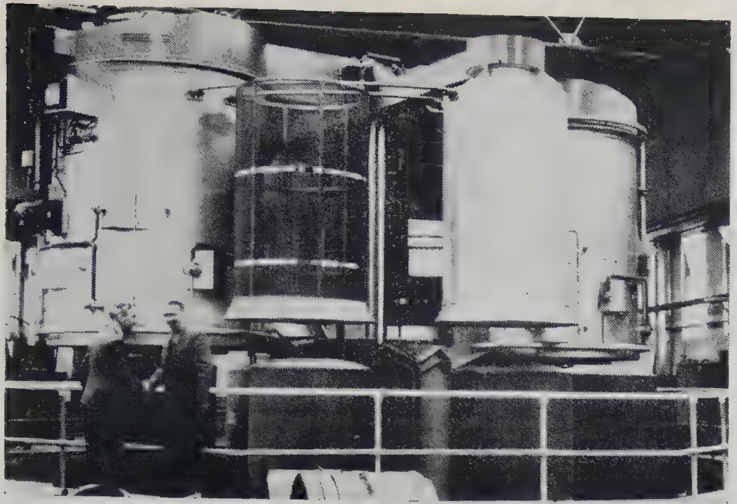
LONDON: 9, BERKELEY STREET, W.1. *Tel. Hyde Park 1711/2*

Sole Distributors for Dipping Tubes in the United Kingdom
THE AMALGAMS CO. LTD., TINSLEY PARK ROAD, SHEFFIELD, 9
LAND PYROMETERS LTD., QUEENS ROAD, SHEFFIELD, 2



A hydraulic circular type annealing furnace for coils up to 48″ diameter—gas fired—installed at

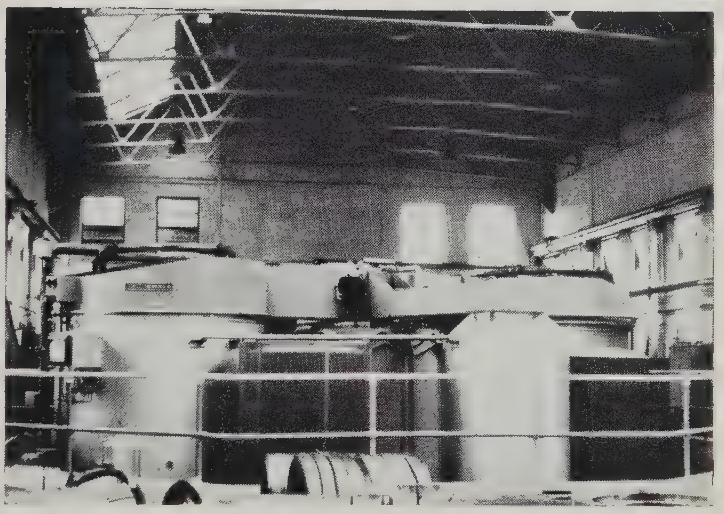
J. J. Habershon & Sons Ltd. Rotherham.

Furnace in raised position

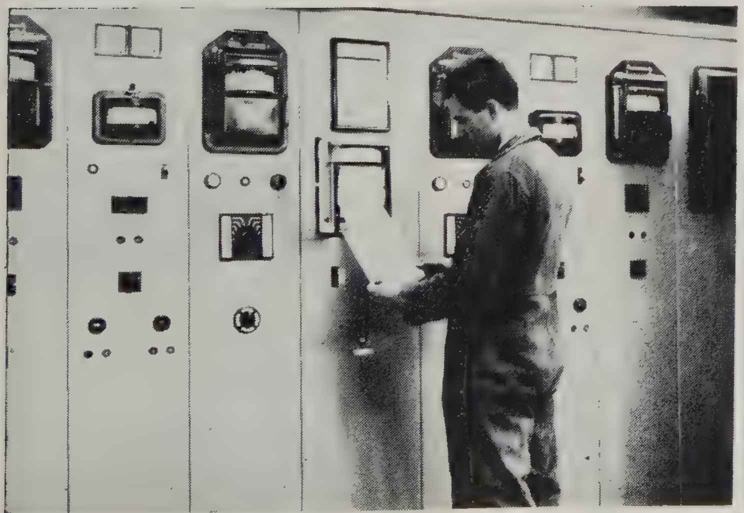
GRUENEWALD

This furnace was installed in May 1960. A second furnace was installed in April, and a third is due in September 1961

Furnace in lowered position



F. W. KUBACH LTD



Part of instrument panel

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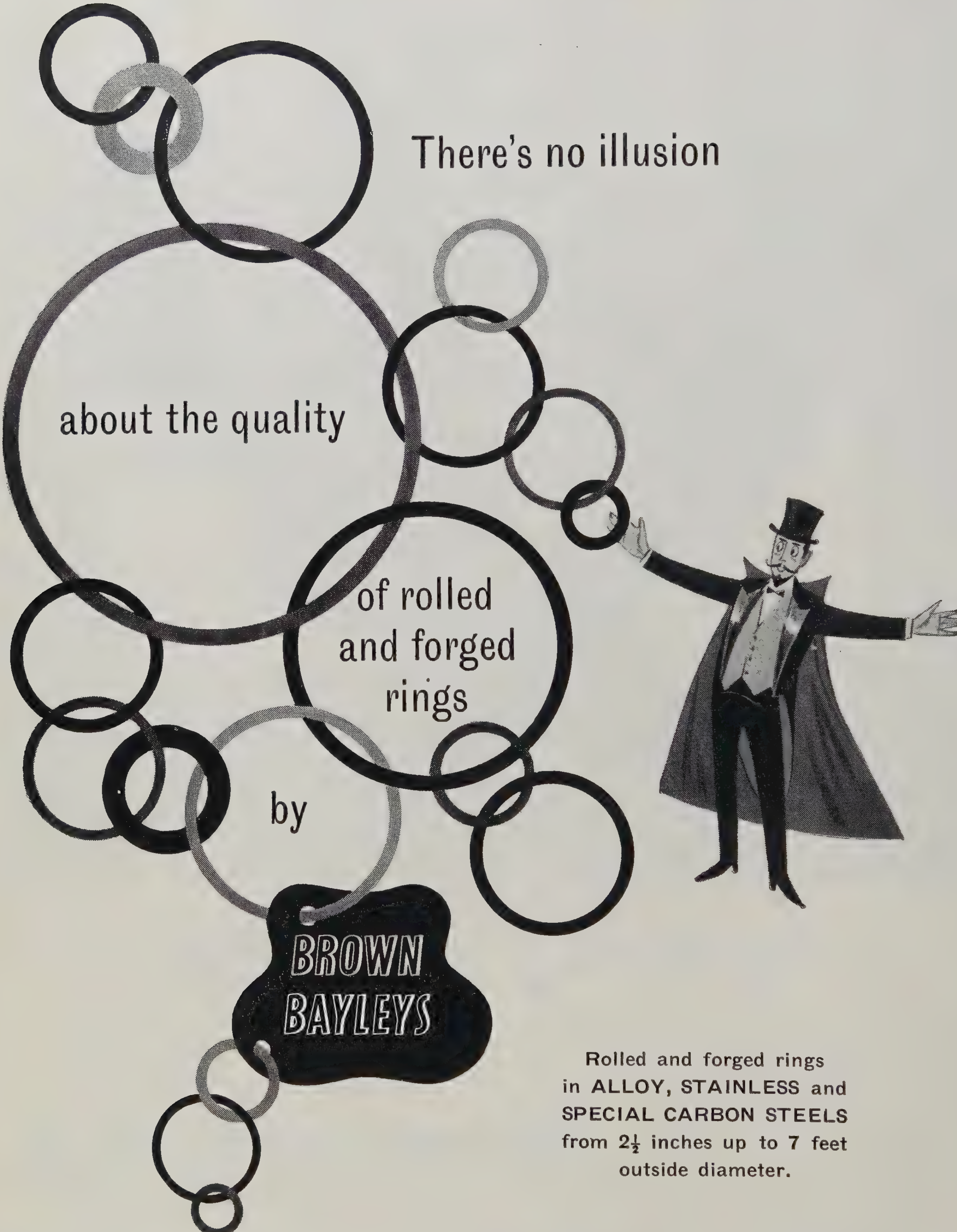
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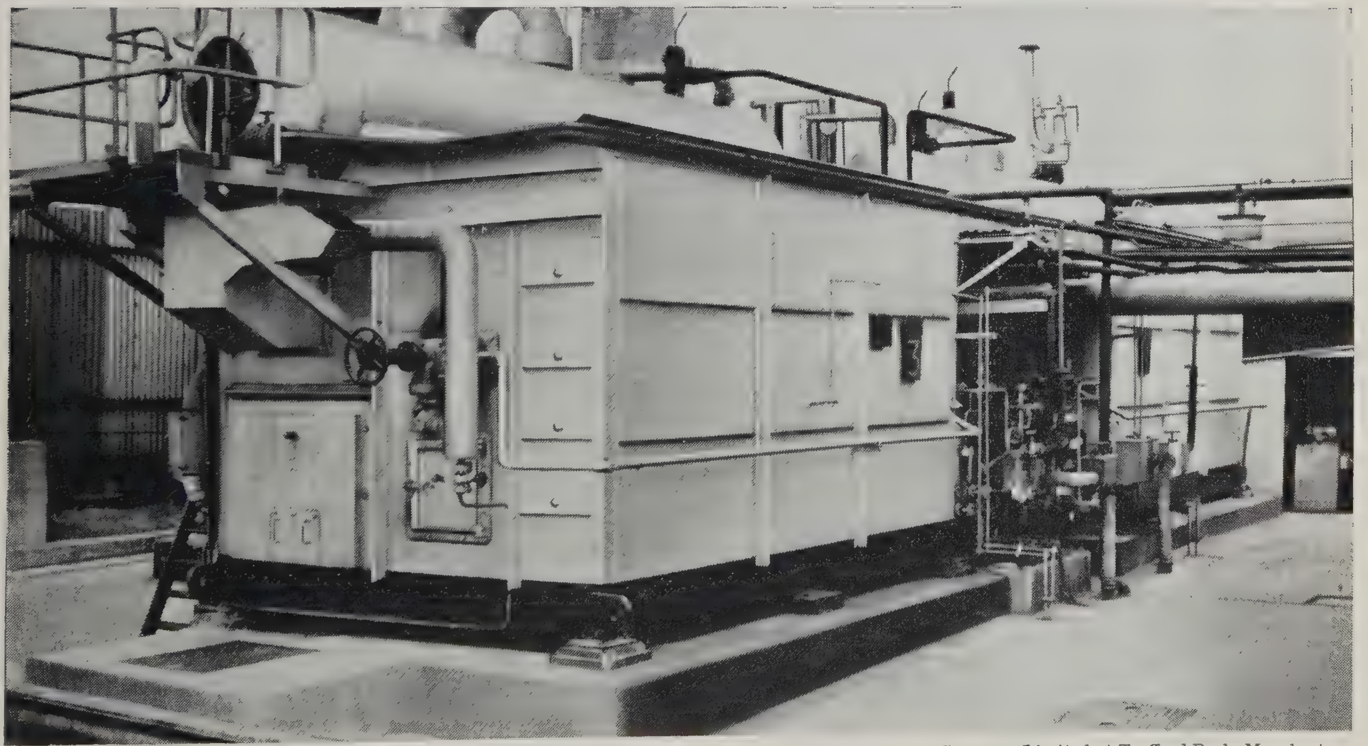

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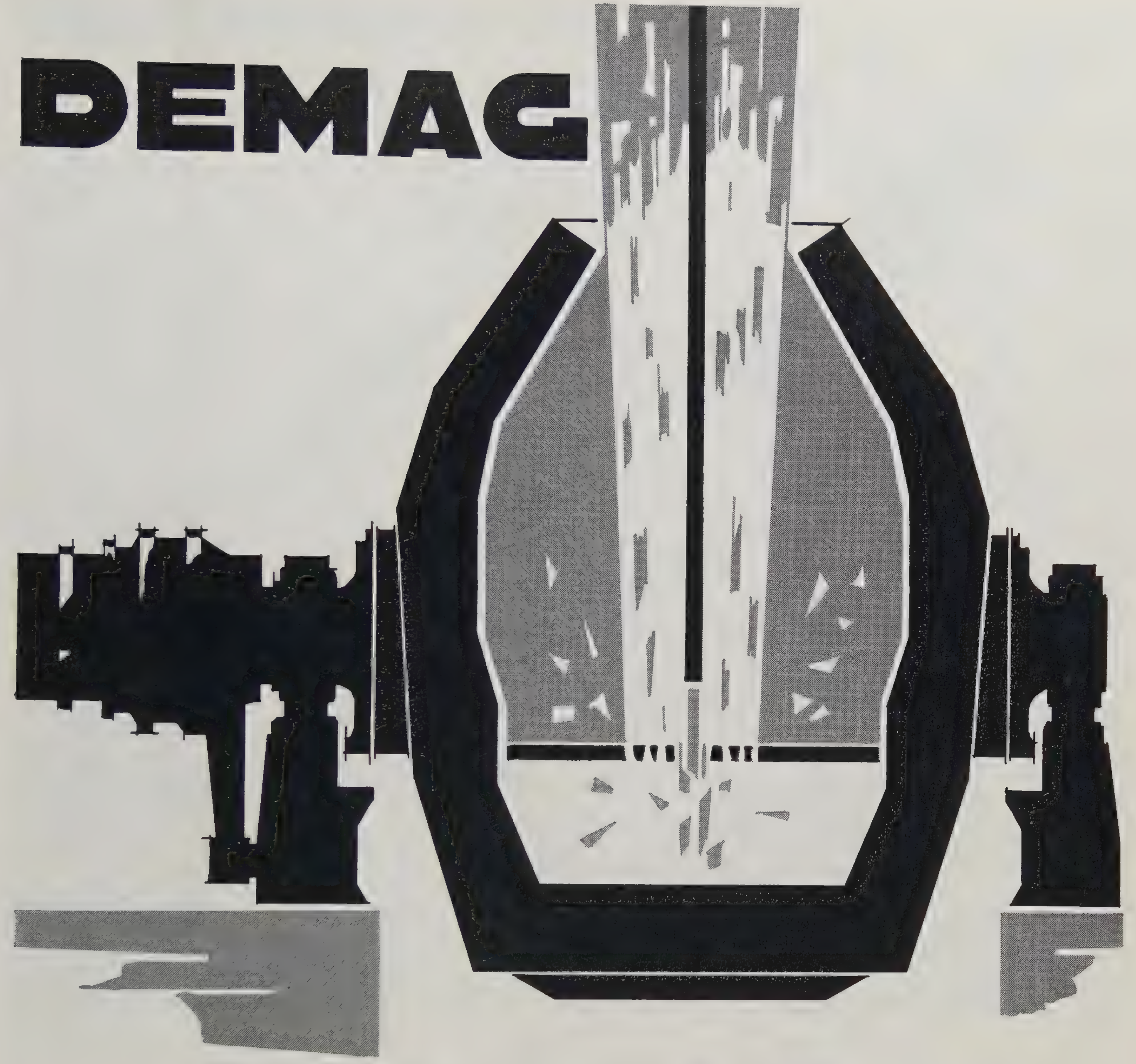

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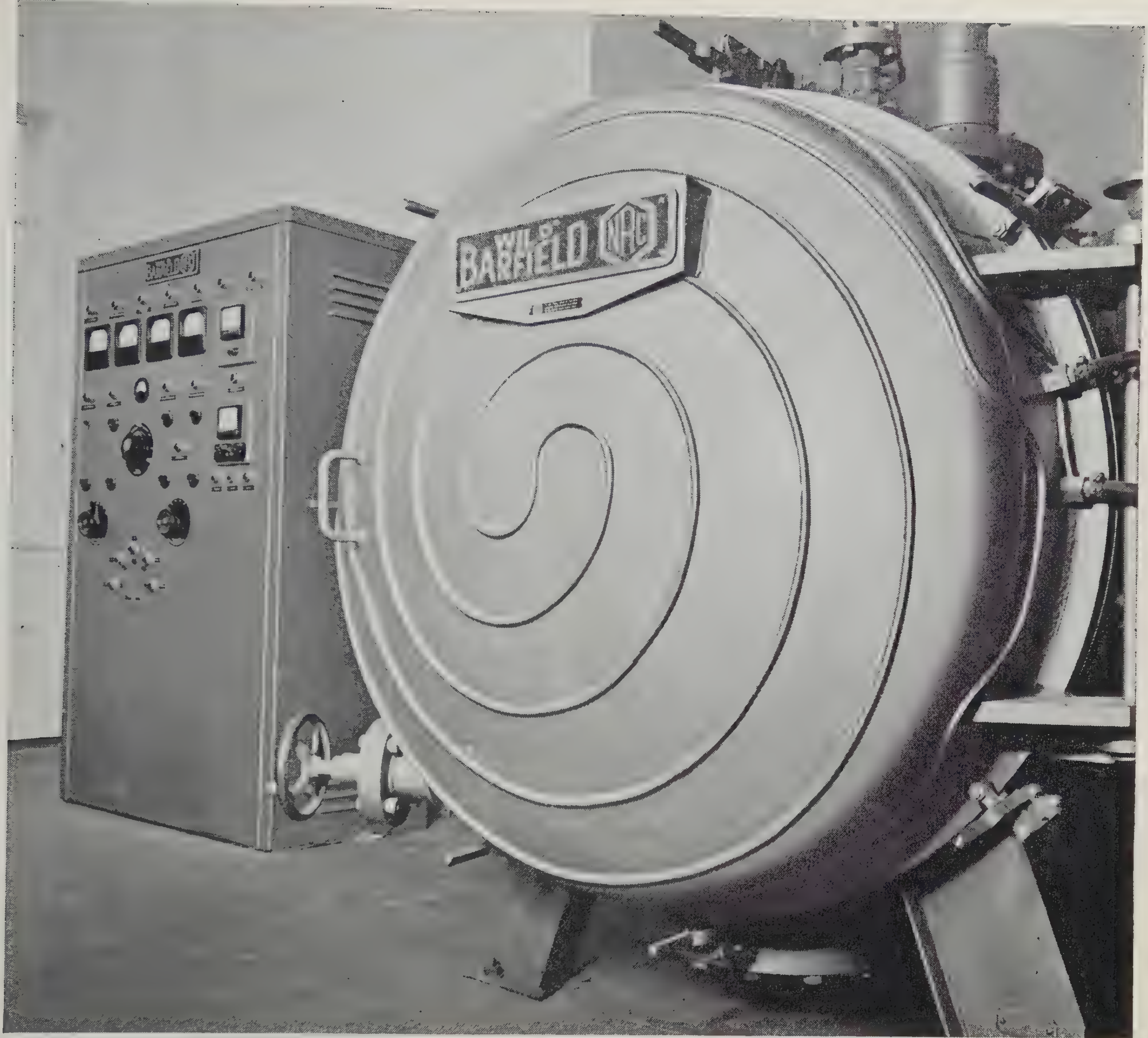
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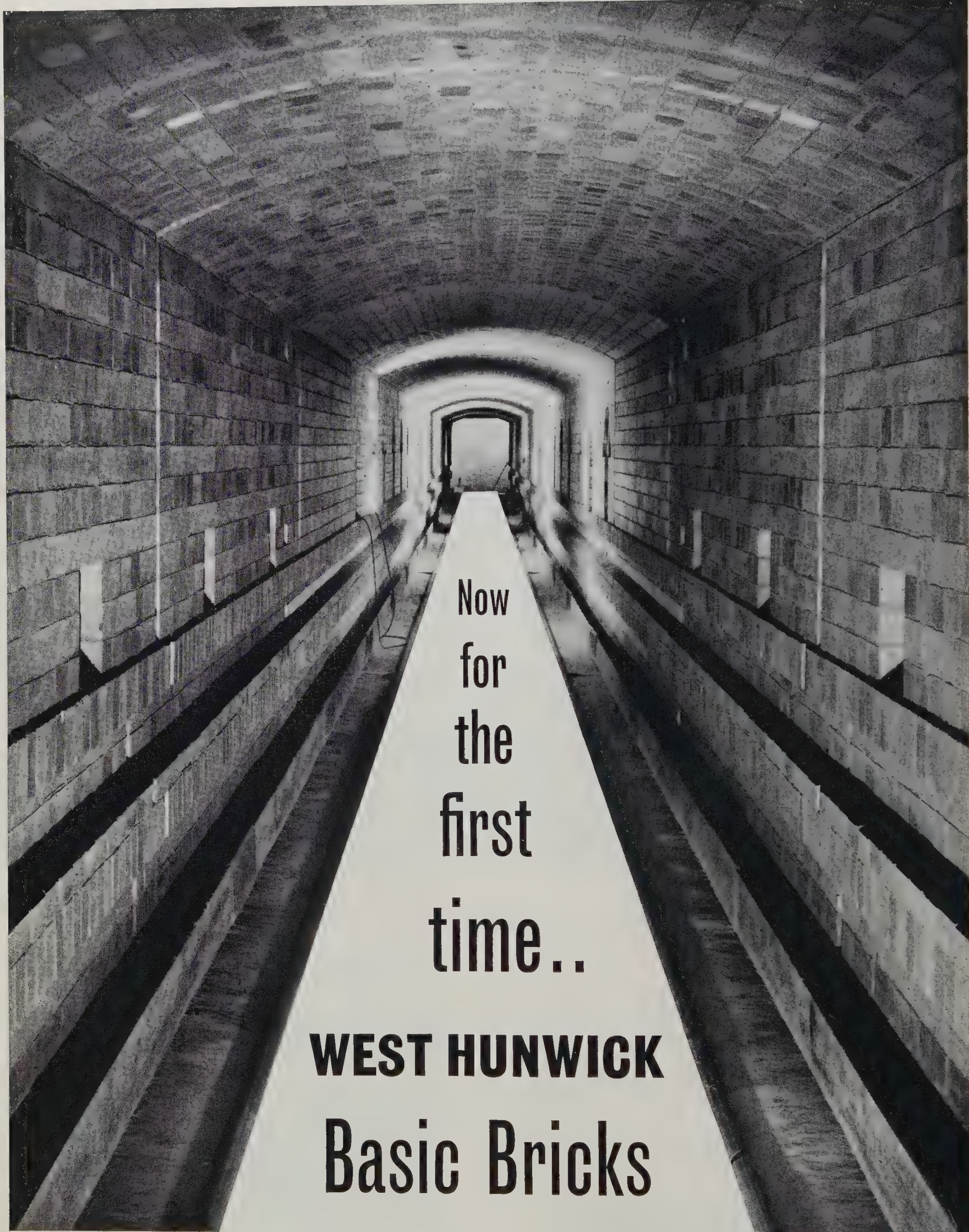
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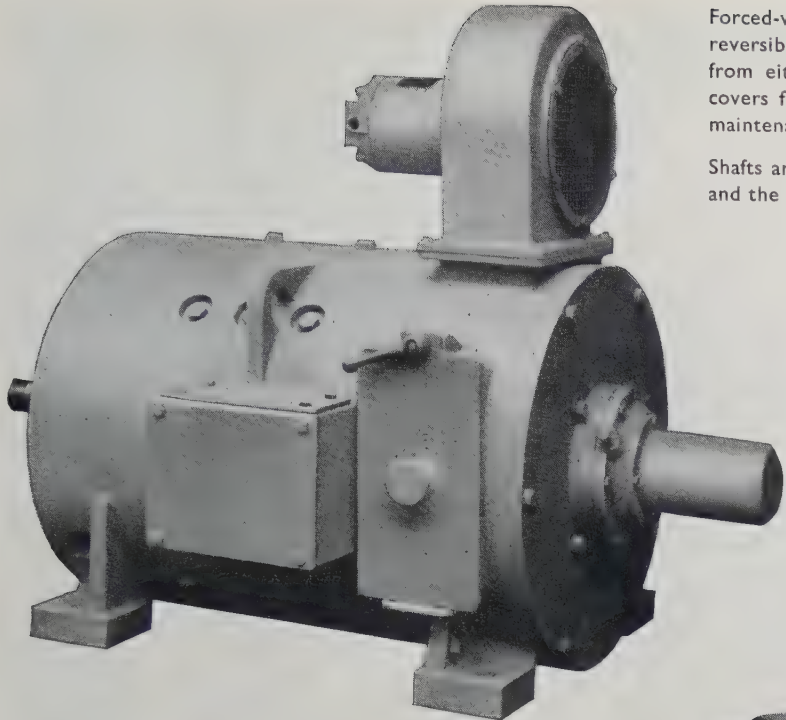

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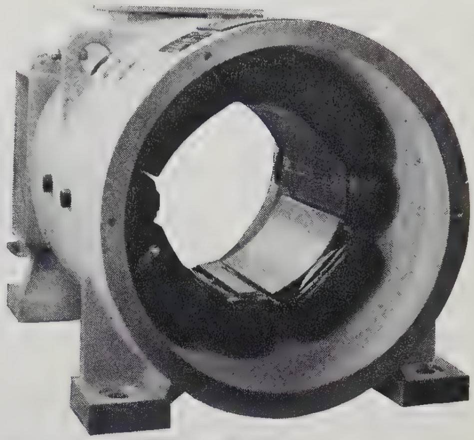

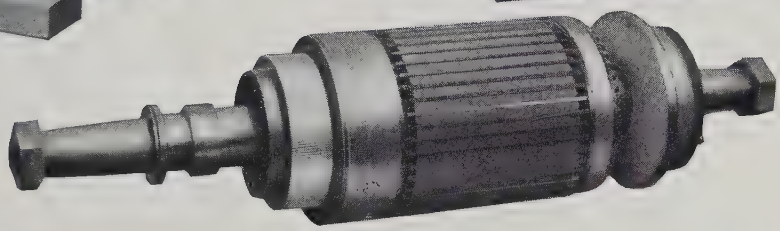

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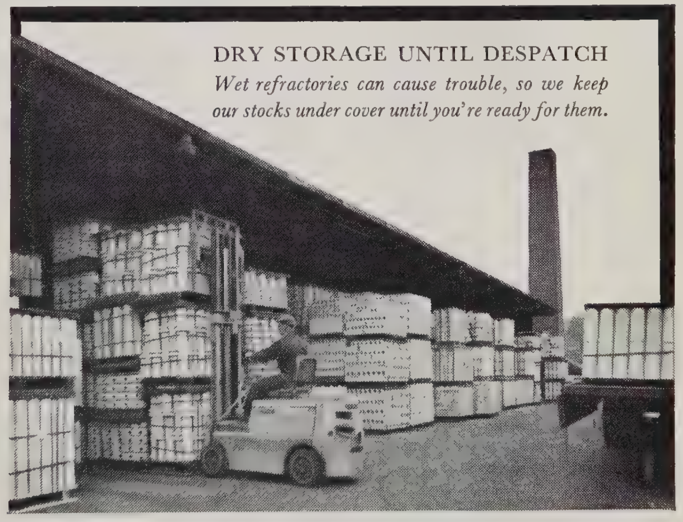

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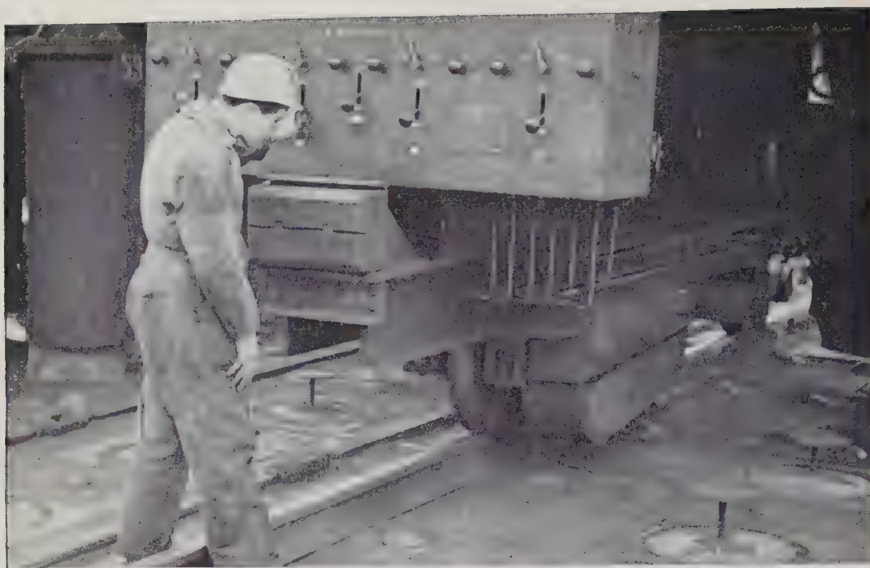

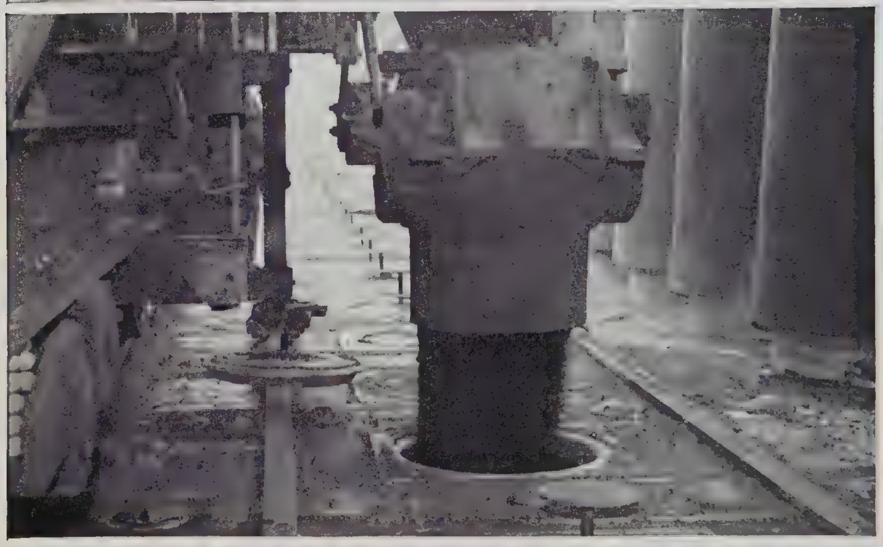

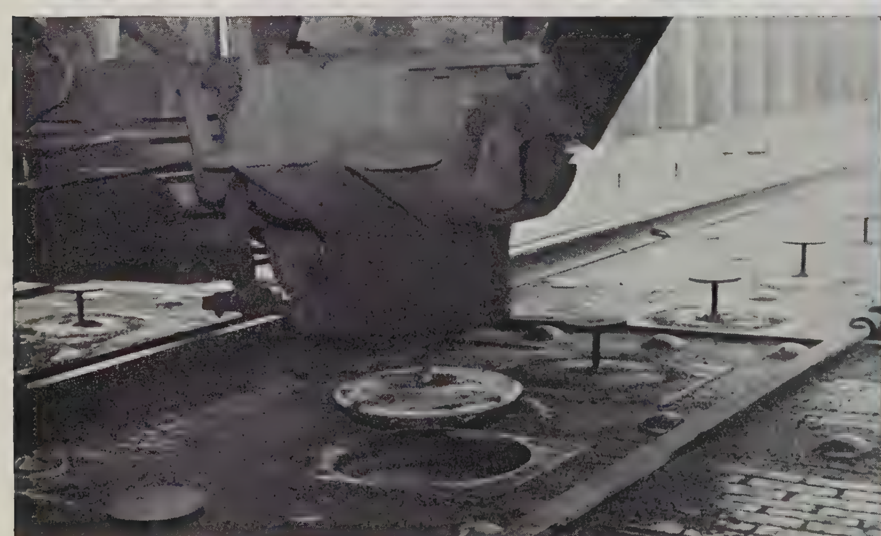

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Contents

THE IRON AND STEEL INSTITUTE
4 Grosvenor Gardens London SW1

H. W. A. WARING, C.M.G., F.C.A.

HENRY WILLIAM ALLEN WARING was born in 1906 and educated at Christ's Hospital. In 1929 he qualified as chartered accountant and until 1939 he practised as a chartered accountant and financial adviser, first in Berlin and Hamburg, and later Oslo, where he was mainly concerned with the reconstruction of a group of Norwegian shipping companies.

In 1939 he was attached to the British Consulate, Oslo, and from 1940 to 1945 he was attached to the British Embassy (then Legation) in Stockholm, first as assistant to the Commercial Counsellor and later as Ministry of Supply representative. For the whole of the war he worked with Sir George Binney, D.S.O., in connexion with blockade-running operations of steel and strategic materials from Sweden to the United Kingdom. In 1942 he took over from Sir George Binney in Sweden and in conjunction with him staged a number of further operations both by sea and air. He was chief British representative in the successful Anglo-American negotiations with Sweden in 1944 to stop the ball-bearing traffic to Germany. In 1945 Mr Waring was decorated with the C.M.G. in recognition of his wartime service.

From 1945 to 1947 he was with the Control Commission for Germany, successively in charge of iron and steel, basic industries, and finally as Deputy Chief of the Industry Division. Mr Waring then joined Guest, Keen Baldwins Iron and Steel Co. Ltd, Cardiff.

He resigned this post on joining the United Nations Economic Commission for Europe in 1951 and he became head of the Industry Division responsible for the international committees on iron and steel, coal, electric power, housing and industry, and materials. During this time Mr Waring visited India, Burma, the USA, and South America. He also visited the USSR, and in 1955, on behalf of the United Nations, he led the first visit of steel experts from the United Kingdom, France, Belgium, and Sweden.

Mr Waring left the United Nations in 1956 to return to industry. From 1956 to 1960 he was managing director of the Brymbo Steel Works Ltd and a director of other Guest, Keen and Nettlefolds subsidiary companies. In 1959 he was elected first British chairman of the Steel Committee of the Economic Commission for Europe and he was re-elected to this office in 1960/61. In 1959 he also represented the Economic Commission for Europe and The Iron and Steel Institute at the formation meetings of the Latin-American Iron and Steel Institute held at Santiago, Chile. He was elected to the board of Guest, Keen and Nettlefolds Ltd in 1960, and on amalgamation of the separate steel companies in the GKN Group at the beginning of 1961 to form the new GKN Steel Company Ltd, Mr Waring was appointed general managing director and deputy chairman.

A member of The Iron and Steel Institute since 1948, Mr Waring was elected to the Council in 1960, and in July of this year he was elected Honorary Treasurer in succession to Sir Julian Pode.

H. W. A. Waring, C.M.G., F.C.A.
Honorary Treasurer

'Steels for reactor pressure circuits'

The report of the symposium on steels for reactor pressure circuits organized by The Iron and Steel Institute for the British Nuclear Energy Conference in London from 30 November –2 December 1960 has recently been issued as no.69 in the Institute's Special Report series.

The introductory address to the symposium, entitled 'Steel and nuclear power', was given by Sir Leonard Owen, member for Production and managing director of the Production Group of the United Kingdom Atomic Energy Authority. It is reprinted here, together with some 'still' pictures taken from the film which accompanied the address.

THE ENGINEERING ACHIEVEMENTS at Calder Hall, the first nuclear power station in the world, were limited probably more by the materials available at the time than for any other reason. Industry, still in the transition from war to peace, found itself unable to provide, without development, materials equal to the requirements, partially no doubt because the great urgency of the military demand inevitably forced engineers to step so far beyond the bounds of experience. Looking back over the years, it is difficult to realize that practices such as the construction, stress-relieving, and pressure-testing of enormous steel pressure vessels on site, now considered as normal, were in those early days of atomic energy the subject of the gravest and most responsible decisions. They were undertaken only because they were regarded as reasonable risks, justifiable in the circumstances. Had the designers of the time not had the courage to take such decisions, the nuclear power programme as we know it in the UK would not have been possible.

Many will be surprised to learn that the Atomic Energy Authority, for its own purposes, is one of the larger users of steel in this country. Its usage of stainless steel has amounted to about 14000 tons at a capital value of £9 m. For their own reactors the Authority has used about 17000 tons of mild steel. Much of this is for completely orthodox usages but in at least two instances, atomic energy has called for steel to meet special circumstances.

In the first, a chemical plant was required for the separation of plutonium from irradiated fuel, using processes involving strong nitric acid at boiling point. No previous user had called for properties similar to those required. Our task was not only the difficult one of designing a full-scale chemical plant to be erected behind thick concrete shielding and never to be approached again, but also to develop in collaboration with industry, a steel suitable for the purpose. The superiority of the new steel specified by us had to be established, joining procedures devised and all the methods of assessment which varied from works to works unified, and this without adding to the short time available to meet the military programme. The size of this project was so great that the UKAEA took the whole of the stainless steel output of the industry to this specification for about two years. It is right to pay tribute to the industry for the way in which it collaborated to supply the materials, but it does not lessen the sincerity of this tribute to express disappointment that a suitable steel was not available without development.

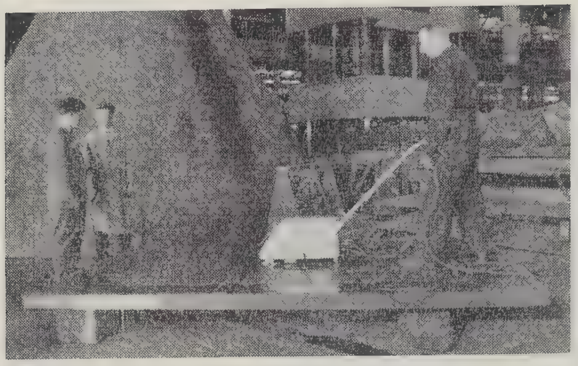
The other major demand made on the steel industry has been for the pressure vessels of gas-cooled reactors. We expected to face difficulties in the fission zone of the reactor, particularly with canning materials, and to have our attainments limited because of the complete novelty of the problem. The limitation did not, however, come from the canning material but from the pressure vessel. Natural uranium was the only fuel available to us and the choice of canning material was immediately restricted to a metal which does not absorb so many neutrons as to interfere with the chain reaction. Magnesium was an obvious choice.

Requirements of reactor pressure-vessel steels

The pressure at which the gas system could operate would be set by the design of the reactor vessel. Taking into account the nuclear characteristics of the core materials, the most reasonable size of vessel to contain the core and fuel handling arrangements was 37 ft dia. and about 70 ft high. Owing to its size, fabrication at site was essential. The maximum current experience of the day was of site welding $1\frac{1}{2}$-in plate in the Bedford wind tunnel. The maximum thickness of plate which we decided we could handle safely on site was 2in. With this thickness of plate the gas working pressure followed at 100 lb/in^2.

The steel to be chosen, in addition to having sufficient strength, had to withstand the temperature of the gas and exposure to nuclear radiation. It had to be suitable for the site welding of such a large vessel and for this reason a low transition temperature was

'Steels for reactor pressure circuits', *ISI Special Report no.69*, 1961, pp.587; price £3 *5s. 0d.* from the Secretary of The Iron and Steel Institute.



1 *Ultrasonic examination of pressure vessel plate*

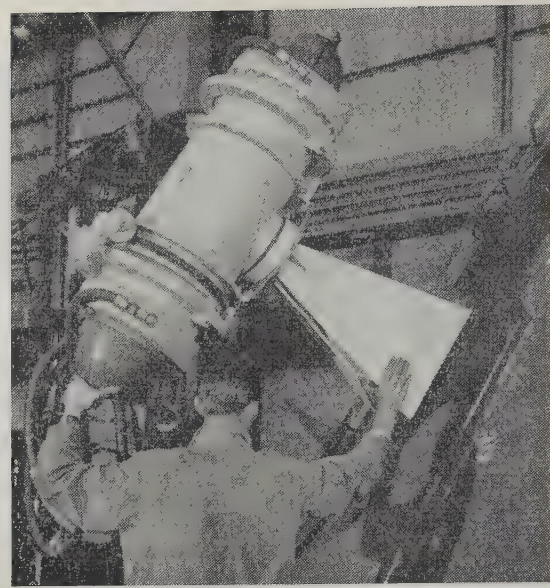
considered preferable. From magnesium fuel elements the gas temperature could be somewhat in excess of 450°C but we could not find a steel suitable for use at such gas temperatures. If we wished to have the low transition temperature to ease the constructional problems on site, we had to limit the maximum shell temperature to 345°C because excellence in transition temperature was not accompanied by superior creep resistance. After satisfying ourselves that no more suitable material was available, we decided on a grain-size controlled mild steel. The output of the reactor was, therefore, limited because 100 lb/in^2 was the maximum pressure which could be used and the temperature of the gas had to be restricted.

The Calder Hall type of nuclear station cost about £200/kW of electrical power installed. This high figure may be justified in a plant built to provide plutonium in the circumstances prevailing at that time but is not acceptable for competitively priced electricity. The cost of nuclear electricity leans very heavily on the capital cost of the station and the primary objective, therefore, in setting up a national competitive industry was to cut the cost per kilowatt installed. One of the most important technical factors leading to economic improvement has been the higher gas pressures introduced progressively in the six years since Calder. The consequential engineering and metallurgical problems related to steel arise directly from the containment of these pressures.

The construction of Calder Hall had clearly demonstrated that large steel pressure vessels could be constructed on site in mild steel 2in thick. Adequate inspection and fabrication techniques now existed to take a further step beyond the bounds of experience. It was necessary to decide whether to introduce a stronger steel or thicker plate.

Aluminium-killed mild steels of high notch ductility and low transition temperature have a reduced creep resistance at temperatures in excess of those in Calder. Normal mild steel boiler plate which can be used at temperatures up to 380°C does not have a low transition temperature and requires difficult and expensive measures to adapt the best shop fabrication practice for use on site. Our need was for a steel superior in strength to that used in Calder, weldable on site, presenting the same advantages as mild steel with its long plastic range. This was the challenge. Could a satisfactory steel be produced and proved in time?

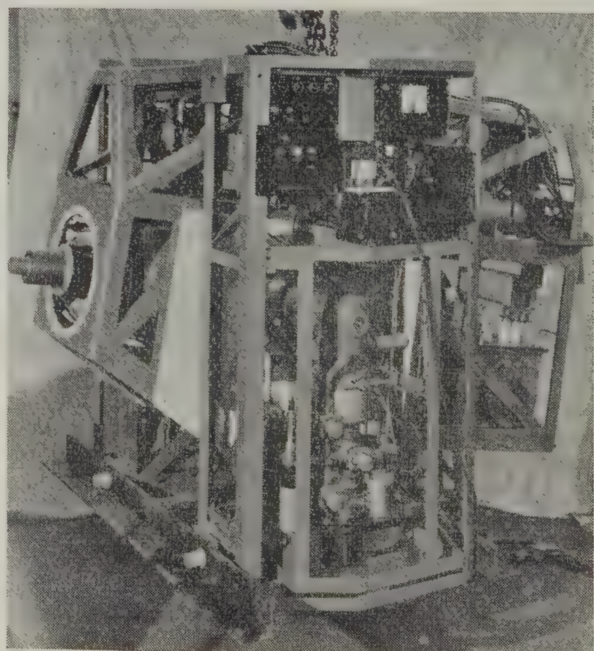
In the event, no superior steel was available and there was no alternative but to carry the design of the



2 *Radiography of a welded assembly, 400 kV X-ray set*

civil stations along the line of improvement of techniques using the same materials as available at the time of Calder Hall but in greater thickness. What was the maximum temperature at which the steel could be used safely if the design code requirements were to be observed? What was the maximum pressure which could be contained? What was the maximum thickness obtainable in homogeneous plates which could be welded and inspected to the high standards required? It was on the answers to such questions that much of the reduction in capital cost would depend.

It is easy to underestimate the difficulties of supply, handling, welding and inspection which can arise from the use of thick plate of specified high quality. These can have devastating effects on costs and programme

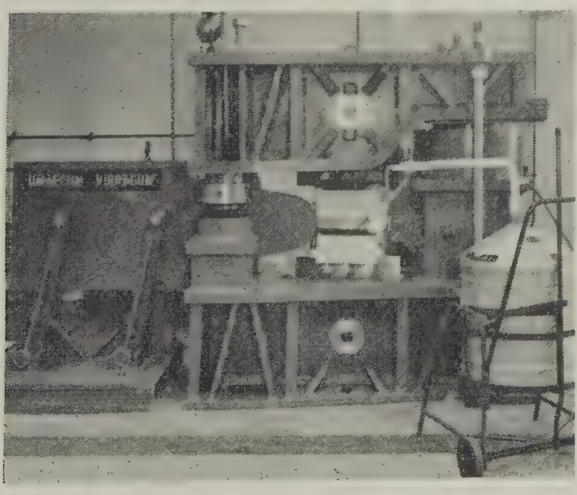


3 *5 MeV X-ray linear accelerator unit under development by Mullard Ltd for site use*

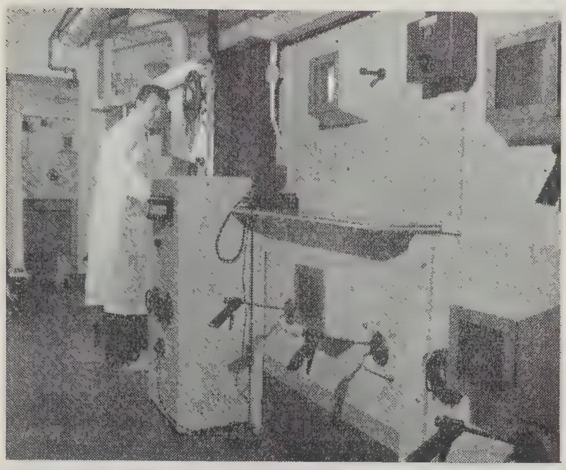
4 *Goliath crane in use at the Hinckley Point construction site*

dates. Notable advances, from which industry in general must benefit, have been made to overcome the problems so that the increasing thickness of plate demanded could be accommodated.

Pressing procedures are now so closely controlled that the standard normalizing treatment can usually be dispensed with. The use and interpretation of ultrasonic methods of inspection (Fig.1) have been so developed that the technique formerly surrounded by controversy is now generally accepted and approved by steelmakers, fabricators, insurance companies and others concerned. For plate thicker than 3in multi-curie source gamma radiography is used extensively on sites (Fig.2). The first 5-MeV X-ray generator developed for use on site is now available for Trawsfynydd (Fig.3) and should be able to extend up to 6in at least the sensitivity and exposure times obtained with 2in plate at Calder. To cope with the increasing necessity for an economic maximum of prefabrication away from the assembly area, site lifting capacity has increased from 100 tons at Calder to 400 tons in stations currently under construction (Fig.4).



5 *600-ton Robertson crack arrest testing machine at UKAEA Culcheth Laboratories*



6 *General view of the Culcheth Charpy testing cells*

Brittle fracture

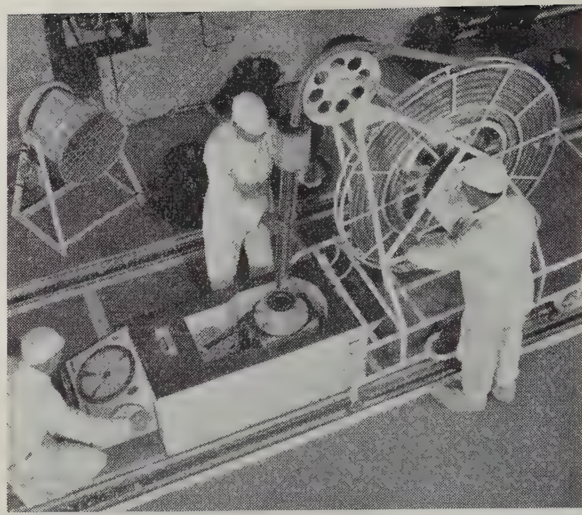
With the use of thick plate there has been a constant awareness of the dangers of brittle fracture. The safety of a nuclear power reactor is of overriding importance and all possibility of fracture of the pressure vessel, leading to the release of radioactivity, must be eliminated. Additionally, precautions are necessary to ensure that there is no danger of cracking during construction on site, due to the additive effects of welding defects, material flaws and locked-in stresses, when temperatures are adversely low in the winter months. The only sure safeguard is to maintain the steel above its brittle transition temperature although the danger is greatly reduced once residual stresses are relieved by heat treatment.

During operation at full power there is, of course, no question of brittle cracking and even during a reactor shutdown the vessel temperature will not fall to the low levels experienced during construction. Account must, however, be taken of the cumulative effects on the steel of neutron irradiation. These cause an increase in transition temperature. The initial ductility of the steel must, therefore, be adequate to meet not only the problems during construction but also the effects during shutdown of any embrittlement caused by the service conditions.

Within the UKAEA, a programme of work commensurate in scope with the importance of this aspect has been carried out to specify quantitatively a suitable test to prevent any plate deficient in ductility from being used in a reactor pressure vessel. The investigations indicate that the Robertson thick-plate, constant temperature test (*see* Fig.5) is the one best suited to determine the temperatures above which cracks will not propagate. This test, requiring sizeable samples of plate, cannot be used as a routine test but the work has shown also that the notch ductility can be controlled at the desired level by the simpler Charpy test (*see* Fig.6). These findings which have led to a more meaningful specification of plate quality, have been accepted by electricity boards, insurance companies and inspection authorities and will be used in specification at least until longer-term experience is acquired.

Stress relief carried out on the assembled vessel lessens the immediate risk of cracking due to constructional stresses but has the effect of raising the

7 *Dimensional check of standpipe positions at Calder*



8 *Television camera in use for internal viewing of a Calder pressure vessel*

transition temperature of the parent plate. This must be taken into account together with the normal thermal ageing of the steel when transition temperatures are to be specified with service conditions in view. Knowledge regarding the effects of irradiation throughout the life of the vessel is not yet sufficiently precise. Provisional and conservative estimates have been made of the effect of irradiation but in each reactor vessel this will be monitored at key positions during the service life (Figs.7, 8). The effects of irradiation on the steel are not expected to place any intolerable restriction on the operator.

Experience has now shown us what the use of thick plate has cost in difficulties right from the steelmaking through fabrication to site assembly and inspection. There is no doubt that good use could have been made of an acceptable stronger steel had one been available.

Alternatives to mild-steel plate?

It is understandable that pressure vessel designers and manufacturers now consider that they know how to build vessels in thick mild-steel plate and would not willingly depart from the proved methods unless the incentives were great. If a new alloy steel were to be introduced they must adopt a proper caution to allow a contingency in cost and time against the uncertainties created by lack of experience.

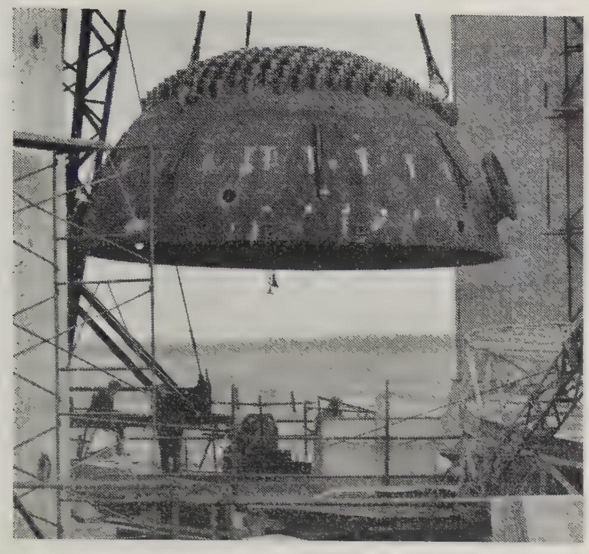
The gas temperature in a magnox reactor is limited by the canning material but is still higher than the maximum temperature to which any available proved steel can be exposed without fear of creep. In existing designs, shell temperatures have been kept low by internal insulation or cooling (Fig.9). Because higher strength steels would be expected to show absence of creep to a higher temperature than mild steel, increased gas outlet temperatures could be contemplated with simpler designs and economies in internal insulation.

So that a higher strength steel with a superior 'no creep' range could be made available, the UKAEA initiated a programme of development with appropriate steelmakers, fabricators and electrode manufacturers. The initial laboratory-scale selection of compositions at the steelmakers was followed by the making of full-size casts and large-scale fabrication trials. As a final stage the programme envisages the incorporation of any new steel in conventional structures showing analogous constructional problems to a reactor pressure vessel. In this way, experience which should go a long way to overcoming initial prejudice to the introduction of an alloy steel will be obtained.

The general requirements were discussed with the British Iron and Steel Federation and it is believed that it is the first integrated programme of such magnitude in this county. Financed extensively by the UKAEA, it was with minor modification adopted by the Nuclear Power Collaboration Committee, representing all the interests of the consortia, the generating boards, and the UKAEA. Such a programme is expensive and, although the benefits will be widely spread, the financing interest is nuclear energy.

A close scrutiny must be made of the real advantages to be offered from the availability of steels say at the 36-ton level. Making favourable assumptions that no large increased material cost will occur, and that no increased site charges due to difficult welding procedures result, it is possible to show a reduction of $2\frac{1}{2}\%$ in the cost of the unit sent out from a 250-MW station by substituting a 36-ton steel of 2·7in thickness for a 28-ton steel in $3\frac{1}{2}$in plate. This assumes that everything except the steel is unchanged. The computation of cost does not take into full account the great advantages which can result on site with the reduction in thickness. Even with welding procedures which may need closer control, factors such as larger and thinner plate, easier handling, less weld metal, inspection by normal radiography, must weigh heavily in the balance.

A higher strength steel makes possible an increase in diameter or an increase in pressure or a combination of the two. Higher strength steels are particularly attractive if large magnox stations are developed to compete with the largest conventional generating units now being installed in the UK. Such stations would have two reactors each of 500 MW(E) output but would be similar in other respects to present reactors. The larger vessels, say 75 ft dia., would be built in thick mild steel but an alloy steel allowing the



9 *Top dome assembly for the advanced gas-cooled reactor at Windscale*

use of thinner plate would be attractive for such a design. There must, however, be full evidence of reproducibility on a commercial scale and all welding procedures must be proved conclusively as being practical and suited to large-scale fabrication. The stronger steel will present its own problems and must compare favourably with mild steel even when used as thick plate. So great is the incentive for the introduction of thinner and stronger plate arising from the saving of weight and the easing of fabrication and inspection procedures that many also wish to see a modification of the design code in the direction of Continental practice of designing on proof stress at working temperature. The advocates of this change claim further economies because of still greater saving of section.

Experience won over generations has, however, shown the great reliance to be placed on the comparatively low yield point and lengthy plastic range of mild steel. Some who argue against alloy steel have this in mind saying also that a change of code with mild steel would still have many advantages. The arguments for and against the substitution of alloy for mild steel in reactor pressure vessels are so far based, unfortunately, on opinions on one side and conservative experience on the other. The only way out of this is for designers to have a more exact knowledge of stress concentrations at changes of section and for them to have confidence that their steels can be made consistently to narrow bands of high quality. This must rely on evidence collected and made available by the steel industry. Although the majority of the steel so far used has been made in the open-hearth, improvements in quality which may arise from more modern methods such as electric furnace and large converters are awaited keenly.

10 *Primary liquid metal heat exchanger circuits for the fast fission breeder reactor at Dounreay*

I have not commented in this paper on the problems of the advanced gas-cooled reactor nor of the fast fission breeder reactor. With the present advanced gas-cooled reactor, ingenuity in design has removed some of the difficulties, but there is still great scope for improvement arising from the availability of improved steels. The problem is different with the fast fission breeder. In the present reactor experiment the circuit is of stainless steel (Fig.10) and there is a compelling economic necessity to employ carbon or low alloy steels wherever possible.

The full benefits of nuclear power cannot be realized so long as the engineer is unduly limited by the materials available to him. If suitable steels are not available he may have to explore alternative materials. The reactor designer feels he is entitled to look to the steel industry for a lead in this problem. I am confident that he will not be disappointed.

ACKNOWLEDGMENTS

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Some aspects of predicting blast-furnace behaviour

A. L. Hodge

INTRODUCTION

DURING THE PAST half millenium probably no industrial process has contributed so much towards man's progress, yet demanded so much towards its understanding, as the iron blast-furnace. Early in its history it was a challenge to the ironmaker and scientist, as it continues to be today, and occupied high priority among all rulers. Many early scientists devoted serious attention to the blast-furnace and made valuable contributions; but common to each development and dissertation was the urgent plea for continued study and additional measurements.

From the 16th to the 18th century considerable thought and writings were devoted to comparing blast-furnace observations and general operating practices. Although technical approaches were limited by the meagre scientific systems of that era, noteworthy advances were made, particularly in England, in predicting benefits of fluxes, blast heating, wind control, and fuels other than charcoal.[1]

Shortly after 1800 Prof. Lampadius suggested dividing the furnace into four zones to simplify study of the many complex interrelated functions.[2]

Following Neilson's invention of the hot blast in 1828, Prof. Clark of Aberdeen in 1834 attempted with little success, to calculate the beneficial effects of heating the blast.[3] Thirty years after Clark's attempt, important theoretical calculations regarding the hot blast and effects of pre-calcination were made by Miller, Truran, Percy, Fairbairn, Mushet, and Dufrenoy. Forty years after Neilson's widely-accepted discovery, Bell stated that the hot blast was still seriously questioned by many, and that 'our knowledge of this subject is too limited to deal satisfactorily with so delicate a matter'.

About the same period, Gruner in discussing a 25000 ft^3 iron furnace producing 80 tons/d asked 'is there no limit to this successive development of the blast furnace?'[2] Then as late as 1918 Johnson stated: 'the chemistry of the blast furnace is not a chemistry of definite atomic proportions. It is a chemistry of infinitely varying balances among conflicting tendencies.'[4]

Shortly following World War II, Linde Company and other divisions of Union Carbide Corporation established a research and development programme to study the blast-furnace. The major accomplishment in this continuing programme has been the development and use of a mathematical model of the blast-furnace based on a complex trial-and-error method readily handled with the electronic computer. In predicting the effects of changing blast temperature, moisture additions, wind rate, fuel injection, and oxygen enrichment, final heat and material balances are closely related to heat transfer, production rate, indirect *v.* direct reduction, top gas temperature, and shaft gas velocity. This mathematical model has been useful in: (*a*) understanding many of the complex interrelationships; (*b*) determining conditions for optimum operation; (*c*) analysing the effect of blast and burden variables; (*d*) making economic evaluations; and (*e*) conducting full-scale furnace test programmes. In addition, this method tied in with an electronic computer shows good possibilities as a means for automatic furnace control. However, the urgent plea continues for better measurements and more accurately controlled furnace test programmes.

SYNOPSIS

A mathematical method for analysing and predicting blast-furnace performance is described, with special attention to several rate processes. These include heat transfer in the shaft, temperature gradients, carbon for direct reduction, hydrogen reduction, and shaft gas velocity.

Principal equations are discussed with examples to show the technological effects of variations in relative quantities of bosh gas and charged solids, production rate, burden ratio, and fuel injection. Possible effects of the water–gas reaction on predicted v. *measured top gas compositions are considered. Programming this method into an electronic computer provides an excellent means for predicting and controlling blast-furnace operation.*

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DISCUSSION

This paper will cover some of the kinetic aspects involved in predicting furnace behaviour and may be considered as part III of two earlier papers.[5,6]

The general functions of the blast-furnace model will be described only briefly since the previous papers

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The author is Associate Manager, Development Laboratory, Linde Company, Division of Union Carbide Corporation, Newark, New Jersey, USA.

TABLE I Normal operating data, furnace Z

1. Hearth dia., ft	29
2. Working volume, ft^3	53 000
3. Shaft height, ft	81
4. Production (basic iron), tons/d (2 000 lb)	2 100
5. Wind (70°F, 1 atm), ft^3/min	108 000
6. Blast temperature, °F	1 350 (732°C)
7. Moisture in blast, gr/ft^3 (dry)	8·5
8. Coke rate (3% moisture), lb/ton	1416
9. Limestone, lb/ton	627
10. Top gas temp., °F	419 (215°C)
11. Top pressure, lb/in^2 gauge	8
12. Calorific value of top gas, Btu/ft^3 (dry)	85
13. Slag volume, lb/ton	905
14. Flue dust, lb/ton	70
15. Water added to skip	none
16. Furnace delays, min/day	15
17. Cooling plates above mantle, rows	16
18. Burden and analyses:	

Burden, %		Top gas, %		Iron, %		Slag, %	
Pellets	63	Co	23·45	Si	1·11	CaO	47·2
Sinter	29	CO_2	14·43	S	0·032	MgO	5·8
Ore	5	H_2	2·40	P	0·110	SiO_2	37·5
OH slag	3	N_2	59·72	Mn	0·88	Al_2O_3	5·9
	100		100·00	C	4·00	S	1·2

19. $CO/CO_2 = 1{\cdot}625$

20. $\dfrac{CaO + MgO}{SiO_2} = 1{\cdot}41$

covered this in detail. Then several aspects of heat transfer and temperature distribution, variations in carbon for direct reduction, hydrogen reduction, and top gas composition will be discussed. An example of predicted results is included showing the effects of making several simultaneous changes in the blast variables. Of particular importance in this discussion will be frequent reference to furnace Z and results which have been presented as the principal example in ref.6. Table I shows average operating data pertaining to furnace Z.

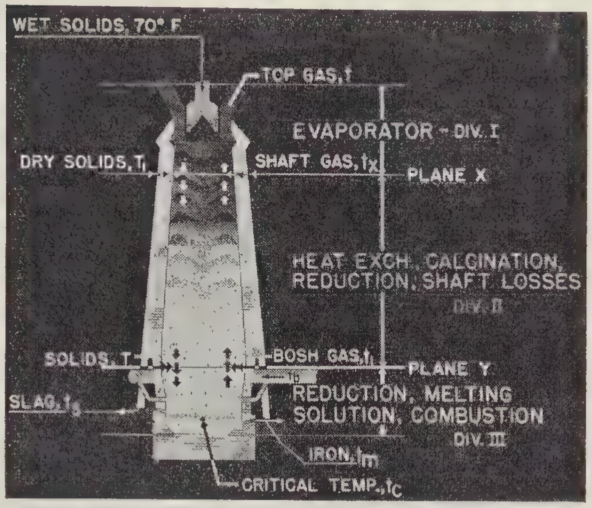
Blast-furnace model

One of the basic factors in developing the analytical model is division of the furnace into three major zones with certain temperature limitation boundaries as shown in Fig.1. Although this figure might suggest that the various temperature planes are horizontal, this is not the case. Actually, the boundaries assumed for each division are taken as isothermal planes irrespective of their vertical loci.

Beginning with the top of the furnace, division I serves as a simple evaporator to remove free moisture from the charged solids and to preheat the solids to 250°F (121°C). The gas enters and leaves this zone at temperatures t_x and t, respectively, with the latter being the final top gas temperature. Little or no chemistry is assumed to occur in this zone between solids and gases although the water–gas reaction may occur, as will be discussed later.

Division II comprises the mid-section of the furnace shaft between the boundary planes X and Y and serves several important functions. With certain assumptions these functions are: (i) heating all solids from 250° to 2200°F (121–1204°C); (ii) complete calcination; (iii) all indirect reduction and reduction with hydrogen; and (iv) 75% of direct reduction of iron oxide (solution loss). Important heat losses are also taken into account within this zone. The shaft gas enters and leaves this zone at temperatures t_y and t_x, respectively.

Division III includes all the active furnace volume below plane Y where it is assumed the following take



1 *Furnace divisions and reference temperature planes*

place: (i) 25% of direct reduction of iron oxide; (ii) formation of slag; (iii) direct reduction of manganese, silicon, and phosphorus; (iv) liquefaction and solution of elements; and (v) high-temperature combustion. The bosh gas leaves this zone at temperature t_y and the temperature of the liquids within the hearth is controlled to some desired value depending upon operating conditions.

To put the thermochemical model to work analysing a specific blast-furnace first requires the computation of a standard case from regular furnace operating data which completely defines a normal or base condition of operation. From data of the standard case several relationships are established which evaluate certain kinetic functions within the furnace when making operational changes.[6] The first of these relationships pertains to the transfer and distribution of heat within division II.

Heat transfer in division II

Frequently the top gas temperature is assumed to remain constant when it is desired to predict the effects of making changes in the blast or charge materials. This results in a simple solution of new heat and material balances compared with a normal operating condition or the standard case. But if these furnace changes are actually tested, the final results could deviate considerably from the initial predictions by unexpected changes in the top gas temperature. For example, an unexpected 100°F (55·5°C) change in the top temperature could mean a difference from the predicted coke rate of 60 to 80 lb per net ton of iron (2000 lb) and an error of 5 to 10% in production.

To evaluate changes in top gas temperature and the final sensible heat lost in the gas, a mathematical relationship is incorporated in the furnace model. Any set of operating changes can be made and the computer begins operation on a preselected trial coke rate. Complete material and heat balances are then computed as well as the top temperature and other effects (Table II). If the sensible heat in the top gas based on the gas temperature is equal to the value obtained by difference in the heat balance, the case is solved. If the deviation between the two sensible heat values corresponds to more than 8000 Btu/ton, the

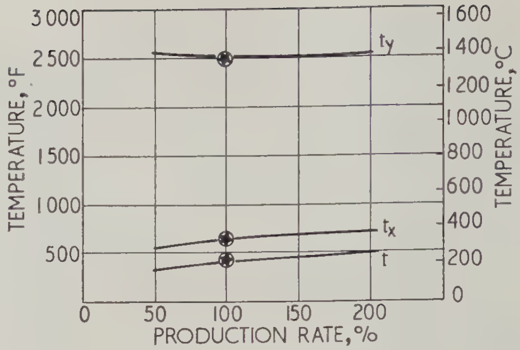
computer automatically iterates upon another coke rate and repeats the computations. The time required for the computer to balance any set of conditions depends on several factors but for the subject program using an IBM 7090 the operation is done in less than a second. Smaller computers such as the IBM 650 and 704 have been found satisfactory but have longer computing time cycles and are limited in storage capacity. Manually, these computations may require 20 to 30 h using good electrical calculators.

The mathematical relationship used in this model to evaluate top gas temperature may be expressed as:

$$[S_b(T-T_1)+(G_d-G_b')(t_x-T_1)+J]=$$
$$\left(\frac{K\theta^n\psi}{2\cdot 3G_b}\right)\left[\frac{(G_b-G_d)(t_x-T_1)+(G_b-S_b)(T-T_1)-J}{\log\dfrac{G_b\,(t_x-T_1)}{G_d\,(t_x-T_1)+(G_b-S_b)\,(T_1-T)+J}}\right]\quad\ldots\ldots(1)$$

in which:

S_b =(lb hot solids at 2200°F leaving div.II at plane Y) × (mean specific heat between 200–2200°F)
T =temperature of hot solids=2200°F (1204°C)
T_1 =temperature of solids entering div.II at plane X=250°F (121°C)
G_d =(lb moles of gas at plane X) × (mean molar specific heat between 200–1000°F)
G_b =(lb moles of bosh gas entering div.II at plane Y) ×(mean molar specific heat at 700–2500°F)



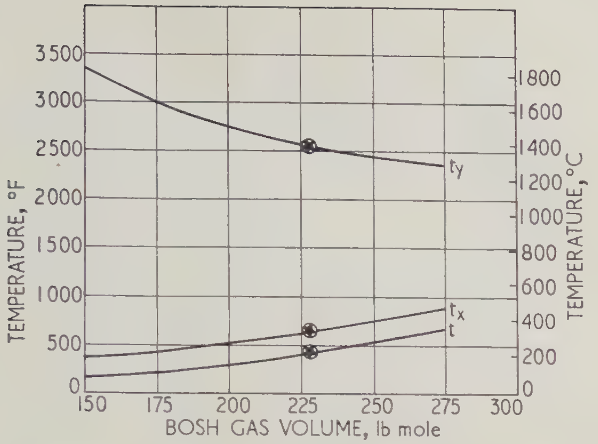
2 *Theoretical effect of production rate on shaft gas temperatures at planes X and Y and the top gas, furnace Z*

G_b' =same as G_b except specific heats are taken for the range 200–1000°F
t_x =temperature of the gas at plane X
J $=\Delta H_{\text{calcination}}+\Delta H_{\text{indirect reduction}}+\Delta H_{H_2\text{ reduction}}+0\cdot75\,\Delta H_{\text{direct reduction}}+0\cdot30\Delta H_{\text{radiation and cooling losses}}$
K =relative heat transfer coefficient between gases, solids, and reactions
θ =relative production rate=1·0 for standard case
n =constant=−0·25
ψ =coefficient for changes in shaft gas velocity=1·0 for standard case.

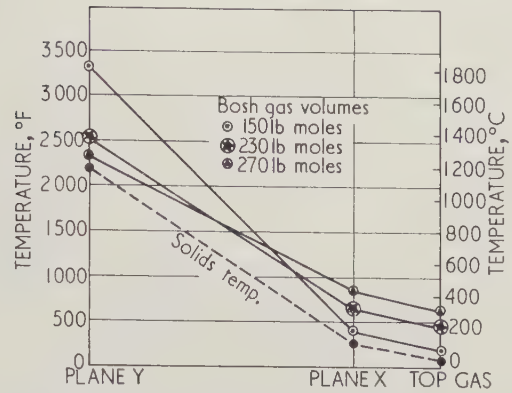
TABLE II Comparison of results, furnace *Z*

	Operating data	Std. case data	Case '*n*' predicted data
Operating conditions (basic iron)			
Ordered wind (70°F, 1 atm), ft^3/min	108000	108000	108000
Blast temperature, °F	1350	1350 (732°C)	1565 (852°C)
Top pressure, lb/in^2 gauge	8·0	8·0	8·0
Oxygen in blast, %	Air (20·96)	20·96	25·0
Methane injected, ft^3/ton	0	0	3000
% of wind at tuyeres	0	0	5·85
Blast moisture, gr/ft^3 (dry)	8·5	8·5	5·0
Slag basicity, (CaO+MgO)/SiO_2	1·41	1·41	1·41
Silicon, %	1·11	1·11	1·11
Burden, same type in all cases	...	...	...
Results			
Production, tons/d	2100	2100	2730
Coke rate (3% moisture), lb/ton	1416	1416	1090
Natural gas, ft^3/ton	0	0	3000
Oxygen, ft^3/ton	0	0	2624
Ore, lb/ton	...	3365*	3371*
Limestone, lb/ton	627	622	584
Burden ratio	...	2·38	3·09
Blast, ft^3/ton (dry)	71424†	68742	51334
Blast, lb/ton (dry)	5329	5129	3851
Flue dust, lb/ton	85	*	*
Slag volume, lb/ton	905	946	896
Composition, %	...	...	...
CaO	47·2	45·0	45·1
MgO	5·8	4·5	4·8
SiO_2	37·5	35·1	35·4
Al_2O_3	5·9	14·2	13·8
S	1·2	1·2	0·9
Top gas, % (dry)	...	...	...
CO	23·45	25·87	24·35
CO_2	14·43	15·92	19·66
H_2	2·40	1·01	5·30
N_2	59·72	57·20	50·69
CO/CO_2	1·625	1·625	1·239
$(H_2+CO)/CO_2$	1·791	1·688	1·508
Calorific value, Btu/ft^3 (dry)	85·0	84·2	91·0
Heat before stoves, 10^6 Btu/ton	...	7·999	6·911
Volume, gross wet, ft^3/ton	...	99862	82645
Volume, gross wet, lb/ton	...	7669	6161
Volume, gross dry, ft^3/ton	...	94990	75969
Volume, gross dry, lb/ton	...	7442	5850
Top gas temp., °F	419	419 (215°C)	376 (191°C)
Gas temp. (t_x) at plane X, °F	...	636 (336°C)	616 (324°C)
Gas temp. (t_y) at plane Y, °F	...	2536 (1391°C)	2614 (1434°C)
Rel. gas velocity at plane X	1·0	1·0	1·05
Rel. gas velocity at plane Y	1·0	1·0	1·10

* No allowance made for flue dust † includes wind loss



3 *Theoretical effect of bosh gas volume/ton on shaft gas temperatures, furnace Z*



4 *Theoretical effect of bosh gas volume on shaft gas temperature gradients, furnace Z*

The derivation and use of equation (1) have been discussed fully with examples in a recent paper.[6] Therefore present discussion will pertain primarily to the thermal functions occurring in div.II. The important variable for solution in the equation is t_x which by simple computation provides the top gas temperature t. In simple terms equation (1) equates the total heat transferred from the gas (left side of equation) as a function of (right side) the logarithmic mean temperature difference between gases and solids within planes X and Y, the production rate, and shaft gas velocity. More explicitly the following terms may be described thus:

$S_b\ (T-T_1)$ = heat transferred to solids within div.II ......(2)

$(G_d-G_b')\ (t_x-T_1)$ = heat transferred to gaseous products formed in div.II from solids such as CO_2 from calcination . (3)

J = chemical heat and heat losses absorbed in div.II

$K\theta^n\psi$ = function of heat transfer coefficient, production rate, and shaft gas velocity ....(4)

$$\left[\frac{\dfrac{(G_b-G_d)\ (t_x-T_1)+(G_b-S_b)\ (T-T_1)-J}{G_b\ (t_x-T_1)}}{2\cdot3\ G_b \log \dfrac{G_b\ (t_x-T_1)}{G_d(T_x-T_1)+(G_b-S_b)\ (T_1-T)+J}}\right]=$$

logarithmic mean temperature difference= ......(5)

$$\left[\frac{(t_x-T_1)-(t_y-T)}{\ln \dfrac{(t_x-T_1)}{(t_y-T)}}\right] \ldots\ldots(6)$$

Equation (5) was developed to eliminate t_y as one of the two variables t_x and t_y in equation (6).

Equation (1) has been applied over wide ranges in studies on some 18 iron and ferroalloy furnaces and found reliable. In proceeding beyond the usual type of furnace prediction, equation (1) has been valuable in showing various thermal effects within the furnace under selected hypothetical conditions. The objective in such study is twofold: first to analyse effects on the temperature of the gas leaving div.III and entering div.I, and second to probe the theory of equation (1).

For example, how are t, t_x, and t_y affected by changes in production rate, θ, when all other variables in equation (1) are assumed constant specifically for the standard case of furnace Z as follows:

$S_b = 4063 \times 0\cdot2573 = \mathit{1045\cdot3}$ Btu/°F
$G_d = 247\cdot47 \times 7\cdot856 = \mathit{1944\cdot1}$ Btu/°F
$G_b = 230\cdot07 \times 8\cdot001 = \mathit{1840\cdot8}$ Btu/°F
$G_b' = 230\cdot07 \times 7\cdot224 = \mathit{1662}$ Btu/°F
$J = 1195607 + 224498/\theta$
$K = \mathit{9882}$
$\psi = \mathit{1\cdot0}$
θ = relative production = $1\cdot0$ for standard case
t = temperature of top gas = *419*°F (*215*°C)
t_x = temperature of gas at plane X = *636*°F (*336*°C)
t_y = temperature of gas at plane Y = *2536*°F (*1391*°C)

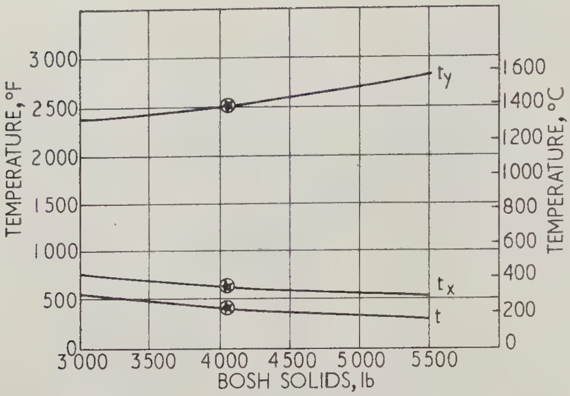
Figure 2 shows the variations in t, t_x, and t_y as the production rate in furnace Z theoretically varied from a normal of 100% to 50% and 200%. The stars in Figs.2–9 signify the standard case values. It should be emphasized that these variations were selected to show *tendencies* with the expectation that the furnace may be thrown seriously out of balance. With increasing production rate two major opposing tendencies in the coke rate can be expected. The constant heat losses per ton should decrease but the heat transfer efficiency from gas to solid should also decrease. This implies that the final thermal effect for moderate changes in production may be negligible as measured by the coke rate with constant blast temperature and with relatively low heat losses. On the other hand increasing the driving rate on a furnace having high heat losses may result in significantly lower coke rates since the savings in distributing the heat losses over a greater tonnage may be greater than the increased sensible heat lost in the top gas.

Analysis of the results in Fig.2 indicates several interesting aspects such as:

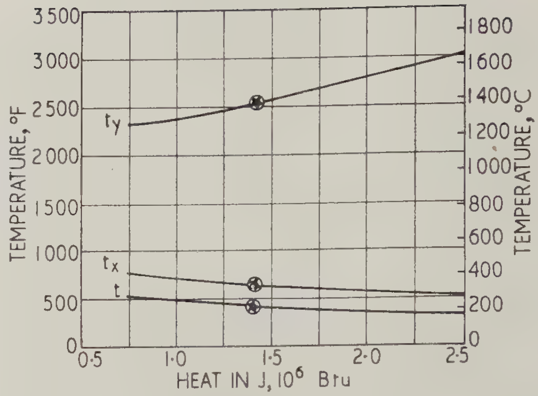
(i) Decreasing the driving rate from 100 to 50% lowered both t_x and t but increased t_y. This would infer the bosh gas entering div.II should be hotter to compensate for the higher heat losses despite the lower top temperature.

(ii) Increasing the driving rate from 100 to 200% shows only a slight increase in t_y but significant increases in t_x and t. This would suggest that little change might be expected in coke rate despite the higher top temperature. Of course there is no indication the furnace could mechanically handle this increased driving rate which is another subject for study apart from thermal effects.

A second aspect to be considered in the heat transfer equation is the influence on t, t_x, and t_y when changing G_b which is a function of the quantity of bosh gas entering div.II from div.III and supplying practically



5 *Theoretical effect of the amount of solids (per ton) entering div. III on shaft gas temperatures, furnace Z*



6 *Theoretical effect of J (Btu/ton) on shaft gas temperatures, furnace Z*

all the heat to the furnace shaft. When making changes in G_b it was also necessary to make the same changes in G_b' since these quantities represent the same moles of gas as defined earlier but with different specific heats. In computing these variations the gas volume of G_b was varied between 150 and 270 lb moles from a normal value of 230·07 lb moles. In actual furnace practice G_b can vary widely due to several causes such as fuel injection, oxygen enrichment, blast temperature, wind rate, moisture addition, and burden changes.

Computed results of these changes are shown in Figs.3 and 4. Figure 3 shows the effect on temperature of changes in the quantity of bosh gas. As may be noted, the temperature in the top gas, t, increases at an average rate of about 3·5°F (2°C) for each additional lb mole of gas, while t_y decreases about 82°F (45°C) for each mole of gas. These curves show the thermal aspects of heat exchange in div.II as related to G_b, but again, it should not be inferred the assumed condition represents a properly balanced furnace. This may be reasoned by the fact that with a much larger increase in the bosh gas, all the temperatures within div.II would tend to approach 2200°F (1204°C). This would indeed fulfil the required thermal functions within div.II but the bosh gas generated within the hearth under these conditions would be at too low a temperature to permit furnace operation. In actual practice or in analysing such conditions by the computer model one or more additional changes would be required for thermal balance.

Figure 4 is another plot of the computed results depicting temperature distribution between plane Y and the stockline for different amounts of bosh gas. The two extreme curves representing 150 and 270 lb moles compared with the standard case value of 230·07 lb moles show a typical lever-arm relationship: that the larger amount of bosh gas entering div.II, the lower its initial required temperature and the higher the temperature of the exiting top gas. Accompanying the gas temperature curves is a plot of the temperature rise in the solids. Relative to the curves of Fig.4, it is recognized that probably no such uniform slopes exist. The actual temperature curves for both gas and solids probably show intermittent periods of halts and accelerations.[7,8] However, for analysis and discussion it is believed satisfactory to connect the different station temperature points with straight lines. It should also be recognized that planes X and Y are not fixed locations within the furnace but that they may move up or down depending on operating conditions.

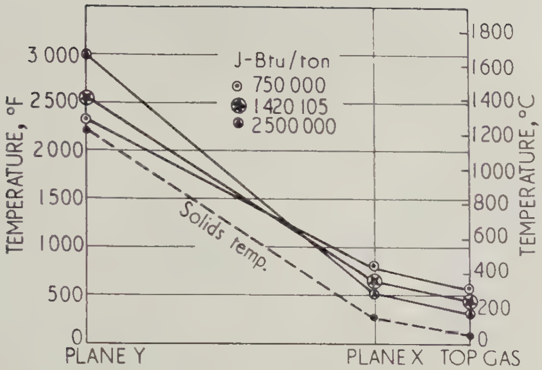
Similar to the above changes in the ascending shaft gas, changes have also been analysed in the weight of solids descending into the smelting zone of div.III from div.II. This particular effect is important since wide deviations can be caused by different slag volumes and coke rates (fuel injection). For this analysis the weight of solids at plane Y for furnace Z amounted to 4063 lb/ton with extreme changes to 3100 and 5500 lb/ton.

Figure 5 shows the computed temperature effects plotted against changes in S_b. As would be expected, the effect of changing the solids is the reverse of that obtained when changing the bosh gas. But again, in actual furnace operation other necessary changes to maintain proper thermal balance between hearth and shaft might alter the slopes of these curves appreciably.

Another very important aspect of equation (1) is how variations in the term J may affect shaft temperature gradients and overall furnace operation. As defined earlier, J includes all the heat transferred from the gas in div.II to chemical reactions and to shaft cooling losses. This indicates that relatively large variations can occur in J due to the use of raw stone *v.* self-fluxing materials, sinter *v.* siderite and limonite ores, and the thickness of shaft lining. The value of shaft coolers is well recognized, but thermally, J increases with more shaft cooling which is a definite disadvantage. J also decreases with increasing production as shown earlier in the nomenclature. In the standard case for furnace Z, J has the value of 1420105 Btu/ton and in this analysis its effect was calculated in the range of 750000 to 2500000 Btu.

Figure 6 shows that these results are similar to increasing the quantity of solids required per ton of hot metal. This similarity is to be expected since proper thermal balancing of the furnace requires sufficient heat from div.III to heat solids, supply chemical heat to reactions, and to offset heat losses through the furnace wall. Also the J curves are similar to mirror images of the G_b curves (Fig.3) since J is a heat consuming quantity while G_b is the primary heat supply function.

The slopes of the curves in Fig.6 indicate that for each million Btu increase in J, the top temperature decreases 127°F (71°C) and the bosh gas temperature



7 *Theoretical effect of* J *on shaft gas temperature gradients, furnace* Z

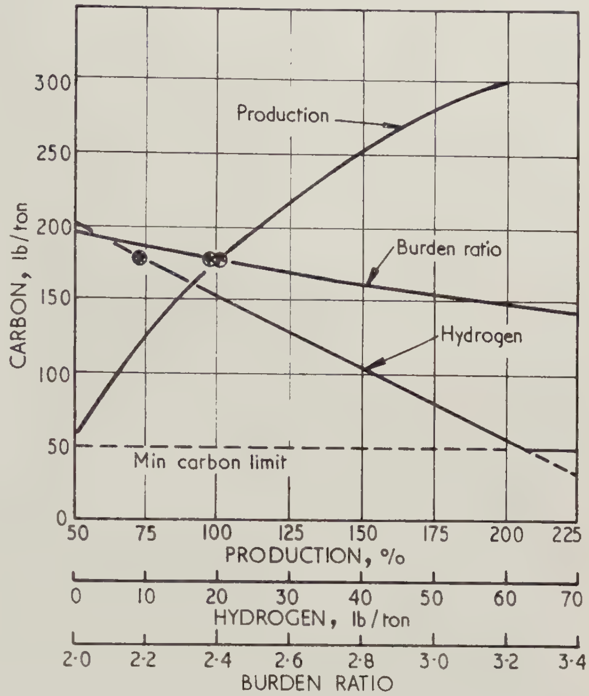
at plane Y increases about 400°F (222°C). In actual furnace operation increasing values of J would require compensating changes in burden ratio or blast temperature to maintain thermal balance. Figure 7 is another plot of the above data showing the temperature distribution above plane Y for three values of J.

The heat transfer equation offers other interesting considerations such as changes in G_d and the effect of furnace design, burden, and charging practice on the coefficient K which is solved from the original furnace operating data (*see* ref.5). Although equation (1) has proven satisfactory, it is difficult to solve manually. Therefore additional data and study might provide a more simple but adequate relationship. One suggestion towards simplification might be to use the arithmetic instead of log mean temperature difference.

Carbon for direct reduction and hydrogen reduction

The function of carbon and hydrogen in the reduction of iron ore has held the attention of investigators for many years. Much is known of the C–H–O–Fe system as related to temperature, but the actual mechanism and chemical side-reactions occurring in the blast-furnace still lack reliable understanding and accurate quantitative measure. In predicting blast-furnace operations assumptions are made to express or evaluate the final (CO/CO_2) and H_2/H_2O) ratios in the top gas. Moreover, it is well recognized that any final optimum furnace results will strongly influence these ratios. Though at the present time the measurement of H_2O in the top gas would be of little or no direct value, the combined measurement and expression of the H_2, CO, and CO_2, is of large importance particularly in view of present trends towards different types of fuel for injection, oxygen enrichment, and furnace control methods. This has made the reliable measurement of top gas composition an important adjunct to optimum furnace control.

In this investigation an empirical relationship pertaining to iron oxide reduction was developed several years ago from actual furnace operating data (equation (9)). This equation expressed the carbon consumed in direct reduction as a function of carbon consumed in the standard case and the relative production rate. The expression was satisfactory until subjected to conditions in which large amounts of equivalent hydrogen were injected into the furnace from steam, fuel gas, oil, or mixtures of fuel, and where large changes occurred in burden ratios due primarily to injected fuel.



8 *Theoretical effect of production rate, total injected hydrogen and burden ratio on carbon consumed in direct reduction, furnace* Z

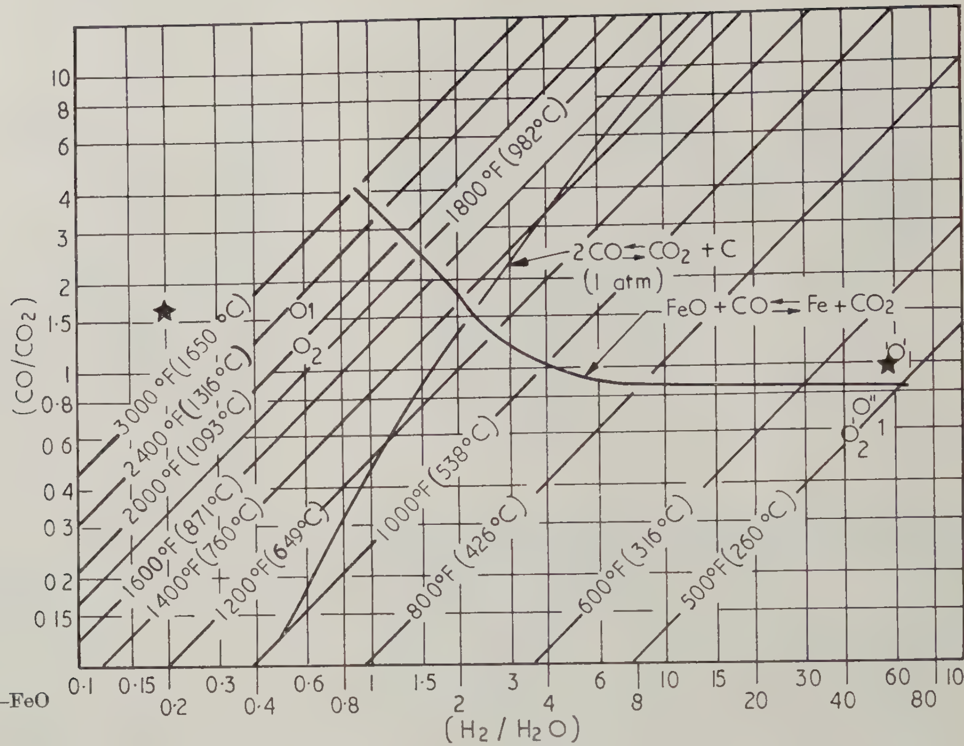
Accordingly the original expression was expanded as follows:

$$C = c - (5{\cdot}96\ e\ H) + a \log \left[\theta \frac{(rd_1 d_2)(d_1' + r'd_2')}{(d_1 + rd_2)(r'd_1'd_2')}\right] \quad \ldots\ldots\ldots(7)$$

in which:

C	=carbon consumed in direct reduction of iron oxide, lb/ton
c	=carbon consumed in direct reduction plus hydrogen entering reduction in standard case expressed as total equivalent carbon=constant
e	=hydrogen utilization efficiency ($H_2 \rightarrow H_2O$)
H	=total equivalent hydrogen available in bosh gas lb/ton
a	=constant solved from standard case data
θ	=relative production rate=1·0 in standard case
r	=burden weight ratio (ore/coke) in standard case
d_1	=bulk density of ore in standard case, lb/ft^3
d_2	=bulk density of coke in standard case, lb/ft^3
r', d_1', d_2'	=values when predicting a case 'n'.

The above relationship was derived and its use discussed in ref.6. However, a simple interpretation indicates the predicted carbon consumed in direct reduction (solution loss) for any set of new conditions depends upon (i) the carbon consumed by direct reduction in the standard case, (ii) the available hydrogen injected, (iii) the production rate, (iv) the bulk densities of ore and coke, and (v) the burden ratio. The terms involving ore and coke densities, burden ratio, and production rate determine the relative retention



9 *Equilibrium system:* $C–H_2–H_2O–CO–CO_2–Fe–FeO$ *and temperature*

time of ore in the furnace. This presupposes that the amount of iron oxide reduced by CO and H_2 depends on the exposure time of oxide to reducing gases. The remaining iron oxide, not reduced by gas, may then be considered as reduced by direct reduction with carbon which is actually the controlling mechanism of equation (7). A good example for analysing this relationship can be shown by considering actual values from the standard case of furnace Z as follows:

c = 199 lb equivalent carbon for direct reduction
e = 0·40, fraction of hydrogen oxidized
a = 411, constant (ref.6)
r = 2·38 weight ratio of ore/coke
$d_1 = d_1' = 130$ lb/ft³
$d_2 = d_2' = 42$ lb/ft³

Substituting the above values in equation (7):

$$C = 199 - 2{\cdot}38\ H + 411 \log \left[\theta \frac{(1{\cdot}345 + 0{\cdot}434\ r')}{r'}\right] \quad \ldots\ldots\ldots\ldots(8)$$

Equation (8) has been valuable for predicting the effects of fuel injection particularly in fuels with different hydrogen-to-carbon ratios. It has also been very helpful in explaining some of the complex functions related to carbon consumed in direct reduction, as well as explaining why in some instances the advantages from fuel injection have been so pronounced. To analyse some of the technical aspects involved in equation (8), values for H, θ, and r' have been varied to show their effect on the carbon consumed, C.

The first relationship calculated was the production rate, θ, over the range of 50 to 200%. Under this condition (H=0) and (r'=2·38) which converts equation (8) to:

$$C = 199 + 411 \log \theta \text{ (original form of equation)} \ldots\ldots\ldots\ldots(9)$$

The second relationship calculated was the injection of 0 to 70 lb/ton of equivalent hydrogen (0–13 500 ft³). Under this condition (r'=2·38) and (θ=1) which gave:

$$C = 199 - 2{\cdot}38\ H \ldots\ldots\ldots\ldots(10)$$

The third relationship involved burden ratios from 2·0 to 3·4 with (H=0) and (θ=1) which gave:

$$C = 199 + 411 \log \left[\frac{1{\cdot}345 + 0{\cdot}434\ r'}{r'}\right] \ldots\ldots\ldots\ldots(11)$$

Calculating the separate effects of production, hydrogen injection, and burden ratio from equations (9–11) resulted in the curves of Fig.8.

From these three curves, increased production exerts the greatest influence in increasing carbon consumed by direct reduction. Although 300 lb of carbon/ton may appear high with high production rates in Fig.8, it should be noted that this carbon value corresponds to 200% production or 4200 tons of iron per day (*see* Table I).

With the assumption that 40% of the total equivalent hydrogen is oxidized by iron oxide which otherwise would react with carbon, each lb of hydrogen (192 ft³) injected, decreases the carbon consumed in Fig.8 by 2·38 lb. Therefore, 3500 ft³ of methane would decrease the solution loss carbon by about 86 lb/ton. Another assumption, used in this relationship, is that irrespective of the amount of hydrogen injected, a minimum of 50 lb of carbon per ton will be gasified by solution loss, hence the limiting break in the hydrogen curve as it intersects the 50 lb carbon level.[9] Of course the hydrogen value corresponding to the minimum carbon value applies only to furnace Z and will vary with other furnaces. The above assumption has been selected as reasonably conservative and will be retained as long as warranted by actual furnace test results.

The curve showing the effect of burden ratio is important particularly where burden ratios change widely by the use of fuel injection. From the slope of this curve and assuming the same ore charged per ton, the carbon for direct reduction decreases 1 lb for each 13·6 lb decrease in coke rate for furnace Z. As discussed previously this effect comes about by occupying the total available furnace volume with more ore and less coke.

As an example to show how all three of the above variables can effect the final carbon for direct reduction, assume the following:

(i) injection of 3000 ft^3 of methane/ton
(ii) production rate = 150% = 3100 tons/d
(iii) burden ratio, $r' = 2{\cdot}95$.

Substituting the above values in equation (8) gives 164 lb of carbon per ton for direct reduction as compared with 199 lb in the standard case condition.

In final consideration of the general relationship for carbon consumed in direct reduction it should be pointed out that this equation has proved very satisfactory even though based largely on empirical data. However, it is believed continuing effort should prove worthwhile towards modifying the relationship, which might include several other factors such as burden characteristics, gas composition, and temperature variations in the shaft.

Top gas composition and hydrogen utilization

It has been long recognized that the chemical composition of the top gas is a good indicator of furnace efficiency when expressed as the ratio (CO/CO_2).[2–4,9] But what about the hydrogen in the bosh gas and its effect as a reducing agent and its effect on the final CO and CO_2 contents? Early thinking considered moisture in the blast as thermally detrimental in the iron furnace because of its large heat of dissociation. But in actual practice controlled steam additions are beneficial.[10] Now the question arises as to the relative effects and benefits to be expected when using injected fuels with wide variations in hydrogen to carbon ratios and with low heats of dissociation. This will include fuels and mixtures varying from coke-oven gas to heavy liquid residuals and coal.

In this work the hydrogen utilization has been taken at 40%, which has provided satisfactory agreement between predicted and actual measured results. But in defining hydrogen utilization some confusion may arise since it is defined as the hydrogen oxidized to H_2O by iron oxide. Also the predicted computer results are calculated on this basis for the final top gas composition. However, it is not to be implied that the final ratio (based on 40%) of the (H_2/H_2O) must equal $(1{-}0{\cdot}4/0{\cdot}4) = 1{\cdot}5$ even after discounting the presence of all other moisture within the furnace. Actually the final measured ratio might be far in excess of 1·5 and still by definition have a utilization of 40%. The reason for this is that there must be interreaction between gases (which can be very rapid) as well as reactions between gases and solids. This complex condition is easy to visualize when considering that there are oxidizing and reducing gases such as CO_2 and H_2O in the presence of H_2 and CO. These are all in close contact between oxidizing and reducing agents such as ore and coke at widely different temperatures.

Some of the reactions which can occur simultaneously at the same temperature are:

$H_2 + \text{ore} = H_2O + Fe$ ......(1)
$H_2O + C = CO + H_2$ ......(2)
$CO + H_2O = CO_2 + H_2$ ......(3)
$CO + \text{ore} = CO_2 + Fe$ ......(4)
$CO_2 + C = 2CO$ ......(5)

Hydrogen in the blast-furnace is a very active reducing gas but from the above, reaction (1) tends to deplete hydrogen while reactions (2) and (3) tend to generate hydrogen. Concurrently, CO is oxidized in both reactions (3) and (4) and generated only in reaction (5). Moreover, in the upper zones of the furnace where carbon exerts little effect on H_2O and CO_2, the water–gas reaction (3) can be very active at the prevailing temperature and catalytic activity. From this the following can be drawn:

(i) the interrelated function of hydrogen may be almost as important with CO and CO_2 as with iron oxide
(ii) thermochemical forces tend to regenerate and preserve hydrogen at the expense of oxidizing CO and C
(iii) true hydrogen utilization may depend more on overall furnace effects than on the (H_2/H_2O) ratio at different furnace levels or in the top gas.

To gain a better understanding of the above it would be worthwhile to measure accurately the changes occurring in the shaft gases, including H_2O, at different furnace heights with changing operating conditions. Also, since CO_2 is a product of both the oxidation of CO and the reduction of H_2O (reaction (3)), substituting the ratio $(CO+H_2)CO_2$ for (CO/CO_2) may be a better indication of furnace efficiency.

Some of the thermochemical aspects of gas–solid reduction in the blast-furnace and top gas composition may be analysed from the equilibrium system C–H–O–Fe shown in Fig.9. On this log-log graph, (H_2/H_2O) and (CO/CO_2) ratios are plotted on the abscissa and ordinate, respectively, with equilibrium isotherms from 500 to 3000°F (260–1649°C). Also included are the equilibrium curves for C–CO–CO_2 and CO–CO_2–FeO–Fe.[11,12] The H_2–H_2O–FeO–Fe equilibrium, though not shown, coincides closely to the CO–FeO, etc. curve.

A simple interpretation of Fig.9 may be shown by the following examples of equilibrium relationships between gas and solids at different temperatures within the furnace shaft.

(i) at 1000°F (538°C) and a (CO/CO_2) ratio of 2·0 the equilibrium (H_2/H_2O) ratio $= 8{\cdot}0$
(ii) at 1400°F (760°C) the (CO/CO_2) ratio in equilibrium with Fe–FeO = 1·8 and the equilibrium $(H_2/H_2O) = 2{\cdot}1$
(iii) at 1500°F (816°C) and 1 atm the (CO/CO_2) in equilibrium with carbon = 9·0 and the corresponding $(H_2/H_2O) = 9{\cdot}0$.

To show how Fig.9 can apply to blast-furnace reactions, four related top gas compositions are considered as follows:

(i) the actual measured analysis from furnace *Z* (col.*A*, Table III) is compared with the corresponding composition (col.*B*) if the gas were allowed to come to equilibrium at a mean temperature between t_x and t or 540°F (282°C)
(ii) the theoretical effect of adding water to the charge is shown (col.*C*) by assuming the moisture content was doubled in the actual gas analysis of furnace *Z* and equilibrated at 510°F (266°C)
(iii) the standard case composition (cols.*D* and *E*) was treated the same as the measured composition in (i) above
(iv) the top gas composition for a predicted case '*n*': furnace *Z* involving oxygen enrichment, fuel injection, etc. (cols.*F* and *G*) was also treated the same as (i) above.

Although chemical reaction rates and environment will also influence final gas composition, Fig.9 can show the driving chemical tendency for the composition to deviate from measured and predicted values. Also these data can help evaluate the reducing potential of gases for different conditions in the furnace.

The following example pertains to the first of the four top gas compositions listed above and plotted on Fig.9.

Actual top gas analysis of furnace Z, with moisture calculated from the total input is located at point $\odot_1$, Fig.9, with (CO/CO_2) and (H_2/H_2O) ratios of 1·63 and 0·59 respectively, and an equilibrium temperature corresponding to about 2300°F (1260°C). But the mean temperature between t_x and t was 540°F (282°C), therefore, calculated equilibrium values for the gas at this lower temperature shift the ratios to point $\odot_1'$ which corresponds to (CO/CO_2) and (H_2/H_2O) of 1·06 and 61·0 respectively. Comparative gas analyses in Table III indicate that if the top gas were brought to equilibrium, the CO would decrease from 22·6 to 18·8% and the H_2 would increase from 2·3 to 6·1%.

The remaining three top gases were analysed in the same manner with the results plotted on Fig.9 and comparative compositions shown in Table III. From these results the following may be noted:

(i) equilibrium conditions at 500–800°F (260–427°C) favour higher H_2 and CO_2 contents and lower CO than normally measured or predicted. Therefore, special care should be exercised in gas sampling techniques and interpreting of data

(ii) at intermediate temperatures of 500–1000°F (260–538°C) water vapour might be considered as 'competing' with iron oxide in reacting with CO

(iii) increasing the concentration of water vapour in the upper portion of the furnace tends to increase the H_2 and CO_2 at the cost of oxidizing CO, hence decreasing the reducing power of the gas

(iv) the water–gas shift decreases the calorific value of the top gas slightly since about 46 Btu of heat are liberated for each ft^3 of H_2 formed by inter-gas reactions

(v) in addition to the chemical analyses shown in Table III, three ways of expressing gas ratios are shown relative to furnace efficiency. For the conditions assumed, the most reasonable appears to be ($CO+H_2$)/CO_2 as suggested earlier.

Shaft gas velocity

In the derivation and use of equation (1) several other useful relationships are available which provide information not already discussed.[6] Among these is a relationship for relative shaft gas velocity at planes X and Y which may be written as:

$$RGV=\left[\frac{\theta V'\ (t_x'+460)\ p}{V\ (t_x+460)\ p'}\right] \qquad (12)$$

in which:

RGV =relative gas velocity=1·0 for standard case
θ =relative production rate
V =lb moles of shaft gas at temp. t_x and plane X in standard case
t_x =temp. of gas at plane X
p =top pressure (absolute)
V', t_x', p'=same as above except for predicted case 'n'.

The use of equation (12) has been useful for adjusting predicted wind rates to reasonable values relative to flue dust and stock movement. It has also been useful in comparing the relative velocities at plane X and plane Y in which the velocity at one plane may be less than normal while the other may exceed normal. This aids in predicting where a furnace may begin pressure build-up and subsequent channelling.

Example of predicted results

To illustrate some of the technical principles discussed and the practicability of using computers to handle a complex blast-furnace model, the predicted results of case 'n' for furnace Z are shown in Table II. This sample set of data is one of 400 cases run on furnace Z in which the following changes were studied:

wind rate, 75000–125000 ft^3/min
blast temperature, 1200–2000°F (649–1093°C)
oxygen enrichment, air to 27% by volume
moisture addition, 5–25 gr/ft^3
fuel injection, 0–6000 ft^3/ton.

Although the results of case 'n' are self-explanatory and have been fully discussed in ref.6, several interesting points may be noted regarding the use of the computer approach such as:

no. cases handled, 400
computations per case, 2000–4000
total numerical answers, 150000–200000
computing time required on IBM 7090, 3 min
time required for manual solution, 15 man-years.

TABLE III Comparative top gas composition furnace, *Z*

	A	B	C	D	E	F	G
				Standard case		Predicted case 'n'	
	Reported normal analysis,* %	Theoretical composition of normal gas at equilibrium, %	Theoretical composition of normal gas with extra moisture added, %	Calc. composition, %	Composition at equil., %	Calc. composition from model, %	Composition at equil., %
CO	22·6	18·8	14·5	24·6	19·8	22·4	14·6
CO_2	13·9	17·7	20·7	15·1	19·9	18·1	25·9
H_2	2·3	6·1	9·5	1·0	5·7	4·9	12·7
H_2O	3·9	0·1	0·2	4·9	0·1	8·1	0·3
N_2	57·3	57·3	55·1	54·4	54·5	46·5	46·5
	100·0	100·0	100·0	100·0	100·0	100·0	100·0
(CO/CO_2)	1·63	1·06	0·70	1·63	0·99	1·24	0·56
(H_2/H_2O)	0·59	61·0	47·5	0·20	57·0	0·60	42·3
($CO+H_2/CO_2$)	1·79	1·41	1·16	1·70	1·28	1·51	1·05
Point Fig.9	$\odot_1$	$\odot_1'$	$\odot_1''$	☆	☆$_2'$	$\odot_2$	$\odot_2'$

* Moisture calculated from total charged

CONCLUSIONS

1. A dynamic model of the blast-furnace process developed from empirical and thermochemical relationships and programmed into an electronic computer, has permitted analysing and predicting furnace operation over wide ranges with excellent agreement between predicted and actual results.

2. In view of the lack of information pertaining to actual heat transfer, solid–gas reduction, furnace movement, and interreactions between gases in the blast-furnace, it is suggested that much more study be undertaken, particularly in the nature of probing the furnace interior.

3. Recommendations would include:
   (i) accurate chemical and physical measurements of gas including moisture and solids at various furnace levels
   (ii) full-scale furnace test programmes with attention focussed on maximum accuracy of all measurements.

4. With reliable measurements, development and broad use of semi-empirical relationships could help bridge the gap between physico-chemical theory and actual operation when predicting blast-furnace behaviour.

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The aerodynamics of gases in continuous furnaces

M. M. Korotaev

SYNOPSIS

High nozzle velocity of the preheated gas–air mixture in a continuous furnace requires careful consideration of the furnace profile if flashback of the combustion product is to be avoided. Euler's theorem is applied in calculating the dynamics of gas flow in the furnace, and the theoretical results correlate well with those found in practice.
1934

In the USSR, many continuous furnaces are fired with fuel gas of low calorific value using injection burners with preheated gas and air.

The combustion of the preheated gas and air up to 300–500°C requires increased output velocities of the gas–air mixture, outgoing from the burner nozzle, to avoid flashback of flame into the burner mixer. With this method of firing, a great amount of energy is introduced into the furnace and if all the burners are directed in counterflow to the stock movement it produces intensive ejection of combustion products during charging of metal into the furnace.

To prevent a direct ejection of the combustion products through the charging door, variable-angle and movable stream screens are arranged in front of the door, though this does not reduce the pressure of the combustion products within the furnace and their leakage through the furnace walls and roof.

As it is impossible to reduce the energy introduced into the furnace owing to a technological requirement of increased velocities during the combustion of the preheated gas–air mixture, other methods of pressure reduction at the expense of the lowering of gas energy within the furnace itself must be sought.

It seems desirable to have such a configuration of the roof of the furnace combustion chamber which

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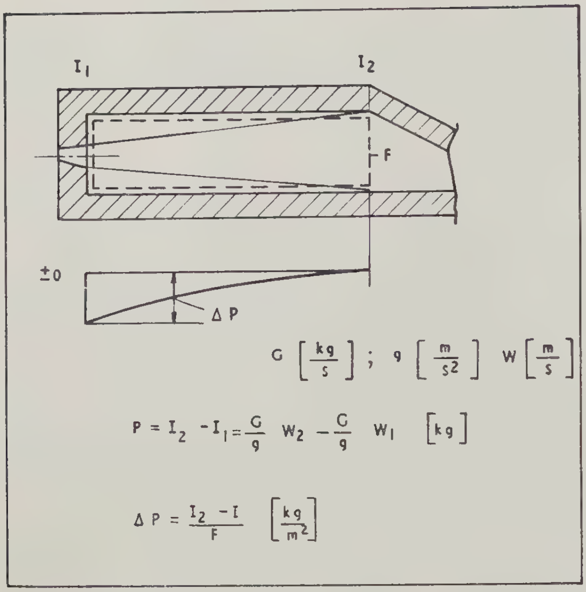
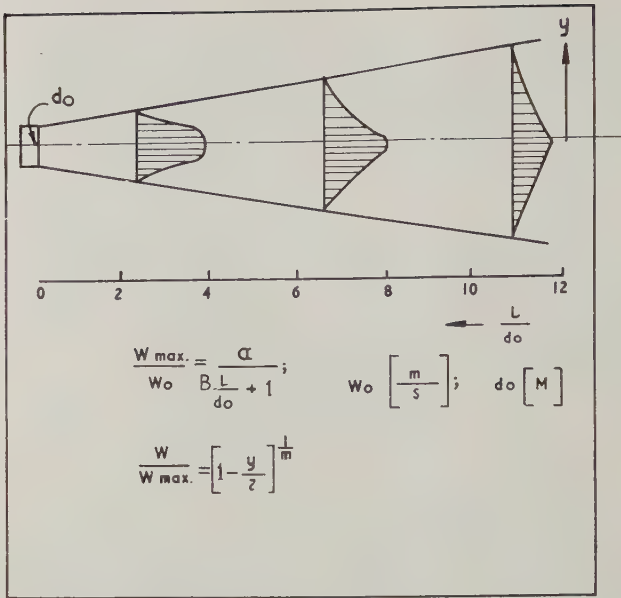
The author is with Stalproekt (state design and planning institute for the iron and steel industry), Moscow.



1 *Portion of furnace, with selected contour indicated by dotted line*



2 *Laws of spread of a free stream*

would provide maximum loss of energy by the combustion products. To determine the effect of roof configuration on pressure distribution along the furnace length, calculations were made of gas dynamics in the furnace, Euler's theorem for equality of the change in the momentum during the time of force application being used for individual furnace shapes.

The application of Euler's theorem in the calculation of furnace gas contours was proposed by G. P. Ivantsov as far back as the 1930's. Euler's theorem for the gas contour can be formulated in the following manner: the difference of the momentum of gas per second, outflowing from and inflowing into the contour projected at an axis is equal to a sum of projections of the exterior forces on this same axis, affecting the gas in the selected contour.

Figure 1 shows a portion of the furnace and the selected contour indicated by a dotted line, application of Euler's theorem to this contour with respect to the axis coincident with the furnace bottom, gives

$$P=I_2-I_1=G/gW_2-G/gW_1$$

where P(kg)=a sum of projections of forces affecting the gas in the selected contour, I_1(kg)=a projection of the gas momentum per second inflowing into the contour, I_2(kg)=a projection of the gas momentum per second outflowing from the contour, G(kg/s)=gas consumption per second, g(m/s^2)=gravity acceleration, W_1 and W_2(m/s)=respectively, mean velocities of gas inflowing and outflowing from the contour (brought to a corresponding gas flow distribution across the stream section).

A projection of forces, affecting the roof and bottom of the furnace, against the selected axis equals zero, therefore the difference obtained of the gas second momentum correlated with the contour cross-sectional area is numerically equal to a pressure difference at the beginning and end of the contour.

$$\Delta p=\frac{P}{F}=\frac{I_2-I_1}{F} \text{ (kg/m}^2\text{) or water gauge.}$$

With the burners installed at an angle to the furnace bottom it is necessary to find the projection of the gas momentum per second at the bottom taken for the axis.

The calculation of gas maximum velocities along the stream axis with the contour length being six to eight diameters of the burner nozzle, is done according to the laws of the spread of a free stream (*see* Fig.2).

$$\frac{W_{\max}}{W_0}=\frac{a}{b\frac{L}{d_0}+1}$$

where $W_{\max}$ (m/s)=gas velocity at the stream axis with the space length Lm; W_0(m/s)=initial gas velocity (velocity of gas–air mixture at the outlet of the burner), d_0 (m)=initial stream diameter (burner nozzle), a and b=test coefficients.

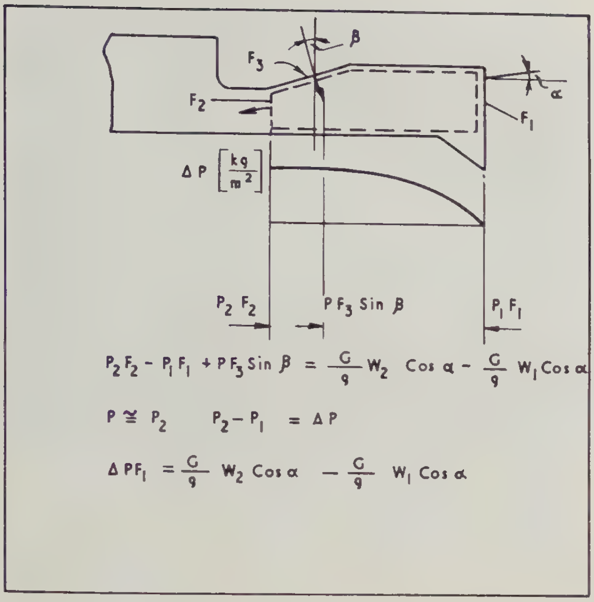
Velocity distribution across the stream is determined with sufficient accuracy by the exponential law

$$W/W_{\max}=(1-Y/r)^{1/m}$$

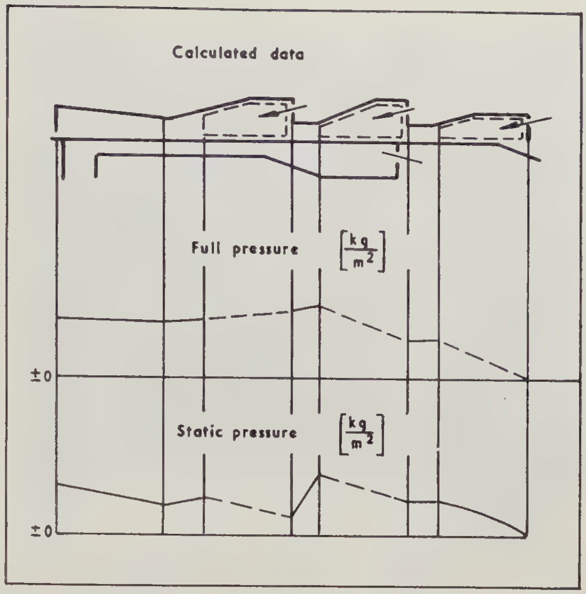
where W (m/s)=gas velocity in the stream cross-section at a distance from the stream axis Ym, r(m)= stream radius at a given cross-section, m=7–8 for the uniform distribution of the gas velocity at the burner outlet, m=1 for the gas velocity distribution on a triangle at the end of the contour.

The calculation of pressure in a continuous furnace starts from the soak zone where at the beginning of the zone at a bottom level the pressure is assumed to be zero. The furnace bottom is taken as the axis of projection. The stream is spread at an angle of about 30°. The place where the stream fills up the height of the combustion chamber, i.e. touches the furnace roof and bottom, is taken as the end of the contour. Projection of forces affecting gas contour from the bottom side of the furnace and parallel part of the furnace is equal to zero.

If an inclined roof is present in the contour, projection of forces working from the side of the inclined roof must be determined. Gas pressure at the inclined roof can be found by means of the parabolic law of the variation in pressure along the contour length with subsequent integration for the inclined roof area and determination of force projection on the bottom area taken for the axis.



3 *Application of Euler's theorem to a selected contour*



4 *Calculated pressure distribution in the upper part of a four-zone continuous furnace*

For the contour selected (*see* Fig.3) the equation on application of Euler's theorem will be:

$$P_2F_2-P_1F_1+PF_3\sin\beta=\frac{G}{g}\,W_2\cos\alpha-\frac{G}{g}\,W_1\cos\alpha$$

with pressure difference at the end and at the beginning of the contour

$$P_2-P_1=P.$$

To facilitate calculation for a case where the pressure on the inclined roof approaches the pressure at the end of the contour we can assumed $P\cong P_2$. Upon reduction, the equation becomes

$$\Delta PF_1=\frac{G}{g}\,W_2\cos\alpha-\frac{G}{g}\,W_1\cos\alpha.$$

The accuracy of pressure calculation depends essentially on the correct determination of the momentum of the gas inflowing into the contour.

The momentum at the burner exit is determined on the basis of the exponential law of velocity distribution over the stream cross-section with a given quantity and temperature of the gas–air mixture.

The momentum of the gas outflowing from the contour is determined on the basis of the exponential law of velocity distribution in the stream cross-section with the quantity of combustion products (obtained from a given volume of gas–air mixture) and their actual temperature at the end of the contour.

Rated pressure difference at the beginning and end of the selected contour represents full head with the combustion products outgoing from the contour. The cross-section of the combustion products, leaving the contour, their temperature, and velocity distribution being known, makes it easy to determine the dynamic head. The static pressure is determined as a difference between full and dynamic pressure.

Variation of pressure between the contour of the soak and heating zones of the furnace is calculated for the flow deformation during straightening of the non-uniform velocities profile, in a flat tube of constant cross-section on the basis of the generalized impact formula.

A coefficient of pressure losses due to flow deformation for a flat tube of constant cross-section during equalization of velocities will be

$$\zeta=1+\frac{(m+1)^3}{m^2(M+3)}-\frac{2(m+1)^{2*}}{m(m+2)}$$

where ζ=losses coefficient co-related with the cross-section at the non-uniform velocity profile, m=a value included in the exponential law of velocity distribution over the cross-section.

Equalization of velocities in a tube of constant cross-section occurs over a length of about six diameters with velocities distribution over the cross-section under the exponential law $m=8$.

If furnace rated length is less than six furnace heights, flow deformation losses are determined by means of linear interpolation as a difference of loss coefficients with $m=1$ and $m=m$.

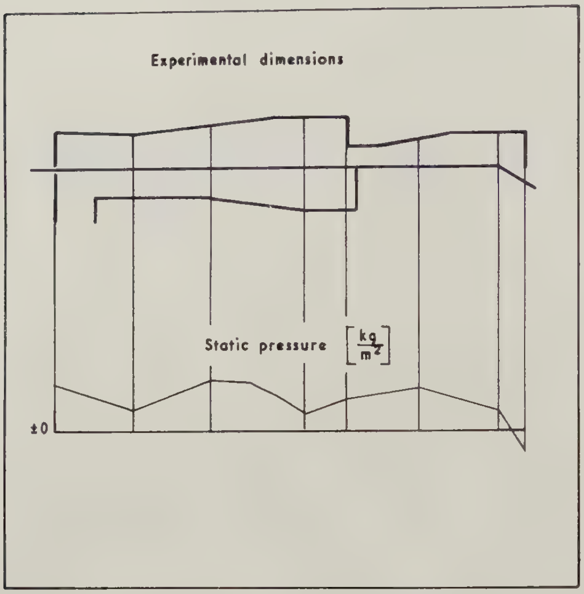
The pressure calculation in the heating zones is made in a similar way, but with different second consumption of gas, the inflow of the gas momentum per second into the contour from the preceding area being taken into account.

Figure 4 shows results of the calculation of pressure distribution in an upper part of a four-zone heating furnace. It will be seen that the heating portion of the furnace is made as a diffuser, therefore, owing to the transition of gas velocity head to static head, the pressure at the furnace charging door is greatly increased.

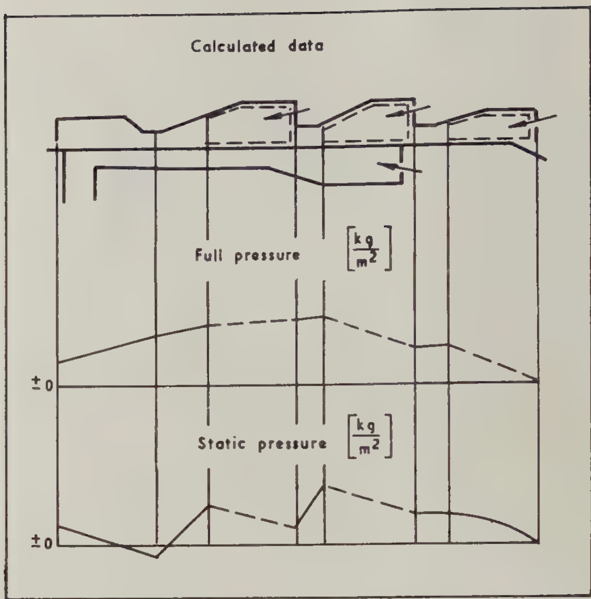
Pressure measurements taken at the charging door of a furnace in operation showed on analysis good agreement of theoretical and experimental data, including gas flow rates. Test pressure measurements taken at the bottom of the furnace with a similar roof configuration (*see* Fig.5) agree well with the character of pressure variation calculated.

To prevent intensive ejection of combustion products from the furnace, calculations were made with modified configuration of the furnace roof. At a

* *See* I. E. Idel'chik: 'Hydraulic resistances', 1954, Gosenergoizdat.



5 *Pressure distribution in the bottom of the furnace*



6 *Theoretical results with changed roof configuration*

point where the second heating zone passes over to the preheating zone the roof is lowered closer to the bottom with sudden widening in the direction of the preheating section of the furnace.

The results of the calculation with the changed roof configuration are presented in Fig.6. It will be seen from the graph that the pressure at charging door was reduced almost by half.

Checking the calculated results on hydraulic models indicates a possibility of using Euler's theorem for the gas contour to determine the character of pressure distribution in the furnace combustion chamber. To simplify calculation a correction was not introduced for the temperature of combustion products when they are cooled in the furnace. Most substantial changes in temperature of combustion products occur within the selected contours and are accounted for in Euler's theorem. Temperature variations of combustion products over different furnace zones do not exceed 200–400°C with a high temperature, and this cannot change the pattern of pressure distribution along furnace length.

For a more accurate calculation of aerodynamics in continuous furnaces, the method of determination of pressure distribution along the contour boundary at the furnace bottom (in Figs.4 and 6 this pressure variation is shown by a dotted line) and working out of more substantial methods of selection of gas contour dimensions in the furnace combustion chamber is of special interest.

Thermal history from corrosion product

P. K. Foster, M.Sc., Ph.D., D.I.C.

SYNOPSIS

X-ray diffraction analyses of scale from a failed boiler showed that part of the furnace tube had been heated above 570°C not more than 16 h before failure. The techniques used offer a non-destructive method of detecting prior heating of steel above 570°C in oxidizing media, and in certain cases of establishing roughly the date of overheating. 1926

INTRODUCTION

THE PROPERTIES of oxides formed on steel, in particular those of wüstite (loosely symbolized as FeO) have permitted useful deductions to be made concerning the service history of an oil-fired steam boiler, normally operating at 150 lb/in^2 gauge (185°C). Catastrophic failure of the boiler occurred, involving collapse of part of the furnace tube, with fracture at or near to the weld joining the rear tube sheet to the furnace tube. As part of a full investigation into the causes of the boiler failure, furnace tube scales from both the top collapsed portion, and bottom of the furnace tube were examined by X-ray powder diffraction. Significant differences in the compositions of the water-side scales from these two locations were observed; these

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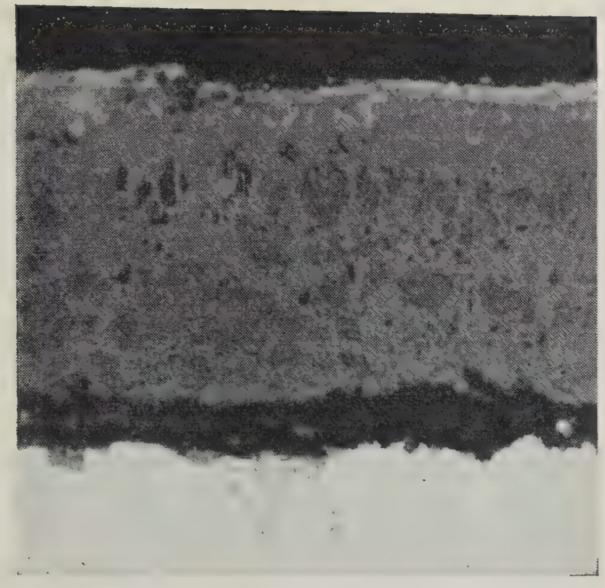
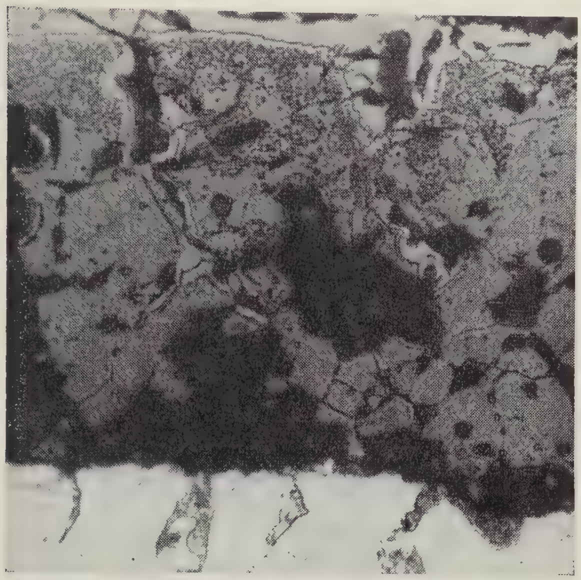
The author is with DSIR, Dominion Laboratory, Wellington, New Zealand.



1 *Metallographic section of water-side scale from A* ×760



2 *Metallographic section of water-side scale from B* ×375

differences prompted the more detailed study of the metal-oxide system which is the subject of this paper. As a result of the investigation a non-destructive method of testing steels for heating above 570°C in service is offered.

EXPERIMENTAL AND RESULTS

Chemical analysis showed that the furnace tube was of mild steel (0·16%C, 0·5%Mn). The only significant impurities in the furnace tube scales were calcium and phosphorus, presumably resulting from the boiler water treatment, on the water side. Manganese (0·25%) was present in both fire- and water-side scales.

As-received furnace tube scales

Areas of the bottom, undamaged part of the furnace tube and of the upper collapsed portion of the furnace tube, designated *A* and *B* respectively in this paper, were selected for examination.

The water-side scale at *A* had an overlying, loosely adherent white layer which was removed with a hardened steel scraper for powder diffraction analysis. The underlying black brittle scale, and similar scales from the furnace side of *A*, and from the furnace and water sides of *B* were removed for analysis with a hardened steel scraper until bare metal was visible over the sampled area.

X-ray diffraction analyses were conducted with a Norelco geiger counter diffractometer using iron Kα radiation.

Metallographic sections of the furnace tube and attached scales were prepared in Formvar 15/95E mounting material as recommended by Hardy and Hopkins.[1] Conventional diamond polishing techniques were used, and the scales etched with 2% nital.

The white overlay was shown to be basic calcium phosphate, $Ca_5(PO_4)_3OH$. No X-ray diffraction peaks were given that could interfere with peaks from wüstite or magnetite.

It must be noted that the wüstite phase has a range of composition[2] throughout which the lattice constant varies smoothly, and increases with iron content.[3] Thus two wüstites of different composition can be identified if their attendant lattice constant difference is sufficient for resolution of the diffraction peaks. A sample of wüstite from a layer whose composition varies through its thickness would give diffuse peaks and no sharp indication of lattice constant.

The samples from the furnace-side scales gave diffraction patterns for magnetite and wüstite. The wüstite peaks from both *A* and *B* were diffuse, and indicated the presence of wüstite varying in composition through the thickness of its layer.

Examination of the water-side scales gave patterns for magnetite, and for wüstite of either of two distinct compositions. The latter will be referred to in terms of their lattice constants (in Å) as FeO (4·30) and FeO(4·33). The water-side scale from *A* gave a weak pattern of FeO(4·33) relative to the magnetite pattern, and FeO(4·30) could not be detected. Water-side scale from *B* gave a strong pattern for FeO(4·30) relative to the magnetite pattern, while some asymmetry of the FeO(4·30) peaks showed the presence in small quantity of wüstite of higher lattice constant. In some samples this could be ascribed to FeO(4·33) but in others the intensity was too low for certainty.

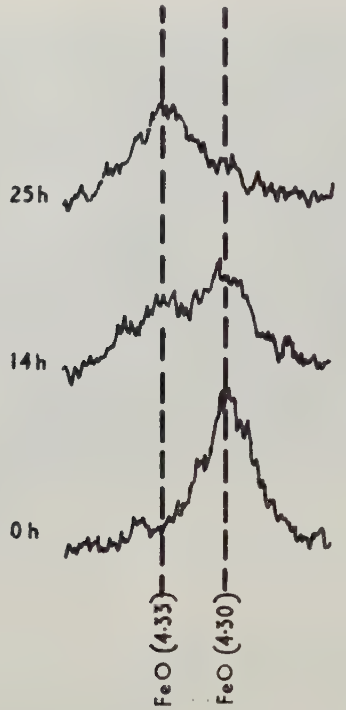
Photomicrographs of the water-side scales from *A* and *B* are shown in Figs.1 and 2, respectively.

Heat treatment of furnace tube scales

Samples of water-side scale from *B* were aged at various temperatures for various times in two ways: removed scale was heated in evacuated Pyrex tubes; and samples of furnace tube, with the scale attached, were heated in liquid oxygen-free distilled water in a small stainless steel autoclave.

The two methods give identical results. The first method was simpler and more generally used.

Mixtures of wüstite and magnetite were equilibrated under vacuum at 900°C in silica tubes. The effect of cooling rate was qualitatively determined by X-ray diffraction of the products resulting from (*a*) quenching in water, (*b*) cooling to room temperature in 5 min. and (*c*) cooling to room temperature in



3 *Diffractometer recorder traces for 220 peaks of wüstite in water-side scale from B, for various times of treatment in liquid water at 230°C*

20 min. X-ray diffraction and metallographic sectioning were carried out as before.

Heating the scales to 180°C and above caused progressive decrease of the FeO(4·30) peak heights and concomitant increase in the FeO(4·33) peak heights, as shown in Fig.3 for 230°C. The results are shown in Table I expressed as the ratio of the intensity of the 220° peak for FeO(4·30) to that of FeO(4·33). The 220° peaks were chosen as offering the best compromise between intensity and resolution.

The effect of cooling rate was such that the water-quenched sample gave a symmetrical 220° peak for FeO(4·30); the slower cooling rates gave asymmetry, that of the sample cooled over a period of 20 min approximating to that of the as-received water-side scale from *B*.

DISCUSSION

In view of the diffuse peaks obtained for the wüstite in the furnace-side scales, nothing of value could be deduced.

The occurrence of FeO(4·33) as a minor and of magnetite as a major constituent of the water-side scale from *A*, can be accounted for. Magnetite is the normal corrosion product of mild steel in water at 185°C. Wüstite in small quantities would result from hot rolling of the plate and stress-relieving of the fabricated boiler before service. Long periods at 185°C would ensure that this wüstite transformed to FeO (4·33).[4] This account is supported by Fig.1 which shows the darker-etching wüstite distributed through the magnetite and apparently taking no part in the growth of the scale.

Of greater importance was the presence of FeO(4·30) as the major constituent of the scale at *B*, and its absence at *A*. The presence of this wüstite shows that *B* was above 570°C when *A* was not. Since FeO(4·30) transforms at 185°C to FeO(4·33),[4] the time of heating above 570°C must have been during the service of the boiler.

TABLE I X-ray diffraction results for heat-treated water-side scales from *B*

Temp., °C	Time, h	Intensity ratio*
...	...	7†
250	49	0
230	4½	3
230	10	2
230	14	1
230	20	0·5
230	25	0·3
212	21	1
190	16	3
180	16	3

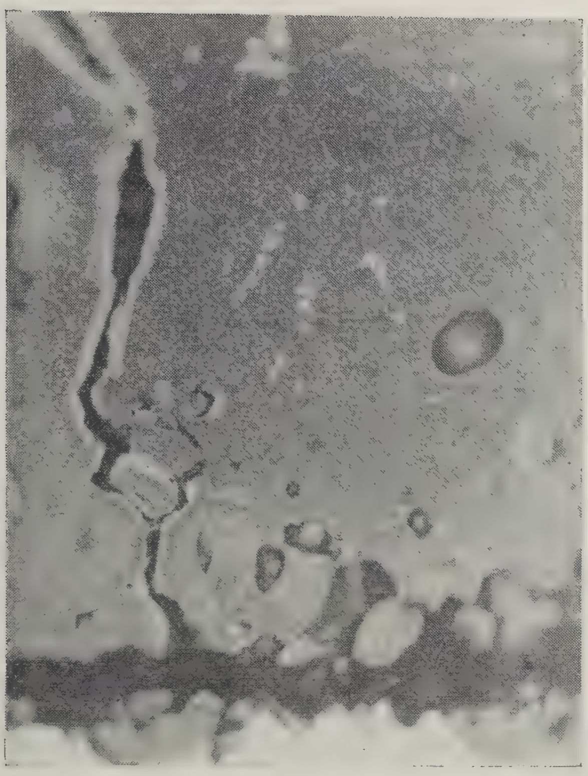
* Ratio of 220 peak heights for FeO(4·30) and FeO(4·33)
† Scale from *B* without heat treatment

Figure 2 confirms the preponderance of wüstite in the scale at *B*. The outlining in Fig.2 of some of the holes in the scale with magnetite is also of interest. This shows that these holes were present in service, and were open to the outer surface of the scale, permitting penetration by liquid water or steam. The remaining holes were either 'blind' to the surface, or, as suggested by the cracks shown in the scale, were formed during polishing of the section. Further, the gap between the scale and the steel may have been responsible for the formation of a wüstite layer of substantially uniform composition, as has been observed elsewhere,[5] rather than a layer of composition varying through its thickness.

The occurrence in the water-side scale from *B* of a small quantity of wüstite of lattice constant higher than 4·30 Å would be expected to result from partial decomposition of FeO(4·30) after the scale temperature dropped below 570°C.[4] This could account for the asymmetry of the FeO(4·30) peaks, and in some cases, the identification of FeO(4·33) in small quantities. Also the presence of a concentration gradient through part of the wüstite layer could cause asymmetry. Evidence for these effects in the present case is adduced below.

The rate of transformation of FeO(4·30) to FeO (4·33) in the range of temperatures likely to be encountered by the water-side scale in service was a matter of some importance, since if it was rapid, the presence of FeO(4·30) after failure, would indicate that the furnace tube was above 570°C close to the time of failure. Accordingly, the stability of the FeO(4·30) in the scale was investigated over the temperature range 180–250°C. If a given time at a 185°C produced as much additional FeO(4·33) as observed in the 'as-received' scale, it was considered that that time could be taken as an approximation to the maximum time required under normal service conditions, subsequent to the overheating, for the formation of the 'as-received' FeO(4·33), i.e. as an approximation to the maximum time interval between overheating and failure. It is a maximum (safe) estimate on three counts:

(i) it ignores service temperature gradients which would cause the scale to be at a higher temperature than the water (185°C),



4 *Metallographic section of water-side scale from B, after 25 h in liquid water at 230°C* ×1220

(ii) it assumes that the asymmetry of the wüstite diffraction peaks was not due to a concentration gradient in the scale

(iii) it assumes that no decomposition occurred between 570°C and 185°C.

Heat-treatment experiments on the actual scale were thought necessary because of the possible effects of impurities on the decomposition, and the disagreement reported over the effect of manganese,[4] which was present at 0·25%.

If the time required for the intensity ratio to change from 7 to 3 is considered, it is clear that the quantity of FeO(4·33) is roughly doubled in 16 h at 180–190°C, and in $4\frac{1}{2}$ h at 230°C (Table I). Although the changes in intensity ratio cannot necessarily be taken to indicate quantitative proportions of the substances, the 'safety' of the estimate permits an upper limit of 16 h to be placed on the time that elapsed between overheating and failure.

The effect of heating the scale for 25 h at 230°C is shown in Fig.4. The penetration of the scale by water in service is again apparent, and haloes of undecomposed wüstite are apparent round particles of proeutectoid Fe_3O_4 and adjacent to the fissure borders of Fe_3O_4.

The absence of transformation in the wüstite close to the metal surface is interesting. Since iron-rich wüstites decompose more slowly than iron-deficient wüstites,[6] this suggests that a concentration gradient did in fact exist over this part of the layer.

The cooling in service of the scale at *B* would be slowed by the 0·5in plate to which it was attached. The cooling rate test results suggest that significant decomposition took place during cooling from 570°C, and this effect, combined with a concentration gradient, could probably account for the observed asymmetry of the as-received scale from *B*, i.e. it is probable that the time interval between heating above 570°C and failure was much less than 16 h.

The detection at *A*, after 13 months' service at 185°C, of FeO(4·33) resulting from manufacturing processes, confirms its long-term stability at lower temperatures, as found by Hoffmann.[4] The transformation rate results are in qualitative agreement with Hoffmann's findings, and to this extent confirm that 0·25%Mn has a negligible effect on the transformation rate. The lattice constant of wüstite would be increased by only 0·0005 Å by 0·25%Mn.[3] This is well within the accuracy of the present work and the effect was not detected.

CONCLUSIONS

Aspects of general importance which emerge from the investigation are:

1. The results depend primarily on X-ray diffraction analysis of the scale, the micrographs being illustrative and confirmatory.

2. The method is non-destructive. It can be applied to cases of suspected over heating, without requiring mechanical testing and/or metallographic sectioning to determine whether temperatures above 570°C have been reached in service.

3. The method is rapid where a Geiger counter diffractometer, with which selected Bragg angle ranges can be quickly scanned, is used.

4. Within the limits imposed by the normal service temperature and the decomposition properties of wüstite, the time of overheating can be dated. This is not possible with other methods of detecting overheating.

5. A further application of the method, not applied in the present work, is the mapping of the overheated area, i.e. determination of the 570°C isotherm for the system, by determining the line of demarcation between areas in which FeO(4·30) was present and areas from which it was absent.

ACKNOWLEDGMENT

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Investigation of abnormal structure in a 1·5%Mn mild steel

B. J. Nield

SYNOPSIS

This paper describes work on the abnormal structures and mechanical properties which are sometimes observed in normalized samples of a 1·5%Mn mild steel currently recommended for the manufacture of colliery haulage and suspension gear. It is shown that the abnormal structure, which may be associated with notch brittleness, is caused by microsegregation of alloying elements: this segregation has been successfully removed by prolonged soaking near 1200°C. A simpler corrective treatment which could be applied to components in practice consists of tempering after normalizing, which removes the tendency to notch brittleness at room temperature and reduces the hardness to a more normal level. 1968

INTRODUCTION

BRITISH STANDARD no.2772: Part 2: 1956[1] gives specifications for mild and low-alloy steels which are considered suitable for the manufacture of components of colliery haulage and suspension gear. These materials have been selected partly because their mechanical properties show good resistance to deterioration in service; this is particularly true of the 1·5%Mn mild steel described in this standard.

Figure 1*a* shows the typical structure of a 1·5%Mn mild steel to BS.2772: Part 2 in the normalized condition; it consists of a mixture of ferrite and pearlite, the latter being readily identifiable. Occasionally however, examples are found in which the normalizing treatment applied to the same section produces a mixture of a pale-etching constituent with the ferrite of the matrix as shown in Fig.1*b*, either in local bands or as a general structure. A disturbing feature is that the abnormal structure is associated with abnormal mechanical properties, the Vickers diamond hardness of the sample in Fig.1*b* being roughly 30 points greater than that of the sample shown in Fig.1*a*.

It seemed probable that the pale-etching constituent which had replaced pearlite in the microstructure was a type of martensite formed at air-cooling rates, and the cause of this effect was sought.

A review of the literature shows that about 1930 considerable attention was devoted to the structure of low-C steels containing 1·5 to 2·0%Mn. At that time trouble was experienced from persistent segregations in steels relatively rich in manganese, these steels often having a coarse dendritic structure, particularly in heavy sections.[2] It was subsequently noted[3] that these Mn steels retain a microscopic segregation resulting from coring unless they are forged or thoroughly hot-worked to an unusual degree. Work on cast samples[4] showed that the observed microsegregation arose during solidification of the ingot and that prolonged heating at temperatures in excess of 1200°C was required to eliminate the segregation, the time and temperature required increasing with Mn content.

Diagrams[3] showing the extra-equilibrium constituents developed in the Fe–Mn–C system by air-cooling indicate that at 0·12%C with 2%Mn and beyond, the structures consist of mixtures of ferrite and martensite, and with increase in the C content, pearlite appears. This composition is quite close to the upper limit of the specification for 1·5%Mn steel to BS.2772.[1] In a more recent discussion of this subject Bain[5] illustrated the marked retarding effect of 2·2%Mn (as against 1·0%Mn) on the rate of transformation of austenite.

The general conclusion from the foregoing work is that the structure developed on air-cooling mild steels containing 1·5%Mn will depend largely on the degree of microsegregation of C and Mn, and on the ruling section. A difference in hardenability between two samples of similar nominal composition could also be caused by the presence in one sample of a small concentration of an element such as boron which may exert a large effect on hardenability, and for which chemical analysis is not usually performed.

Experiments were devised to determine which of these phenomena was the cause of abnormal structures occurring in 1·5%Mn steel.

PROGRAMME OF EXPERIMENTS

The following series of experiments was performed:

(i) samples from the normal and abnormal steels were subjected to comprehensive chemical and spectrographic analysis

(ii) preliminary attempts were made to correct the abnormal structure by conventional heat treatments

(iii) normal and abnormal samples were cooled at various rates from the austenite temperature

(iv) abnormal samples were subjected to prolonged heating at high temperatures

(v) mechanical tests were performed on normal and abnormal samples, and on abnormal samples after corrective treatment.

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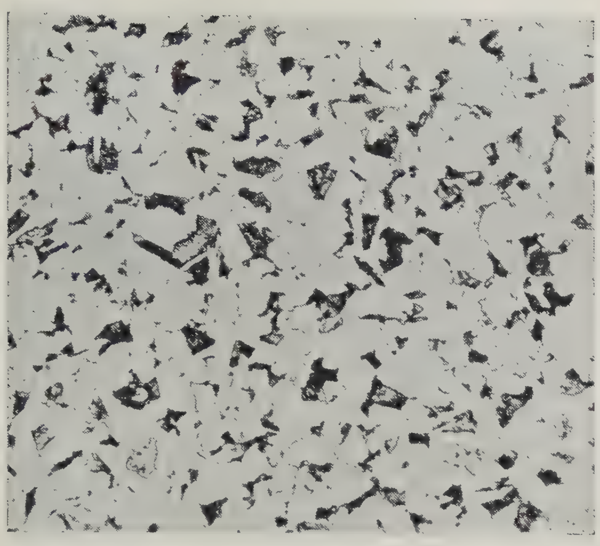
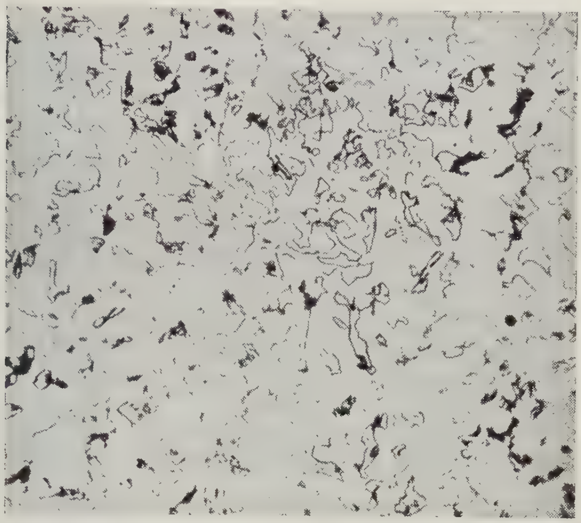
The author is with the Ministry of Power, Safety in Mines Research Establishment, Sheffield.



1a *Typical structure of a* 1·5%Mn *mild steel, as-normalized* ×300



1b *Abnormal structure found in some samples of* 1·5%Mn *mild steel, as-received* ×500

Results

Chemical and spectrographic analysis

Normal and abnormal samples subjected to chemical analysis gave the results shown in Table I.

For both samples the limits of other elements detected spectrographically were:

	%
Cr and Mo	< 0·05 each
V	< 0·03
W, Co, and Ti	< 0·02 each
B	< 0·001

The C content of the abnormal sample was considerably in excess of that specified for 1·5%Mn steel to BS.2772. There were no significant differences in the contents of principal or trace elements to suggest that an appreciable difference in hardenability would be observed between the two samples.

Preliminary heat treatment

An abnormal sample in the as-received condition was normalized from 890°C: this caused an increase in the proportion of the pale-etching constituent, the resulting structure having a Vickers diamond hardness of 202. The same sample was tempered in a vacuum furnace for 1 h at 630°C and cooled at an initial rate of about 20°C/min. The distribution and order of size of the second constituent remained unchanged but it now showed some internal structure: examination at ×1500 magnification showed that carbide precipitation had occurred in both spheroidal and lamellar forms (Fig.1*c*). The Vickers diamond hardness of the sample was now 158, showing that the abnormally high hardness could be corrected although the structure was not normal. Annealing an abnormal sample from 900°C converted the second constituent into a dark-etching form resembling fine pearlite (Fig.1*d*); the distribution of the second constituent strongly resembled that due to interdendritic segregation. A water-quenching and tempering treatment exerted no influence on the structure obtained by a subsequent normalizing treatment, which remained abnormal.

TABLE I Composition by weight of normal and abnormal samples of 1·5%Mn mild steel

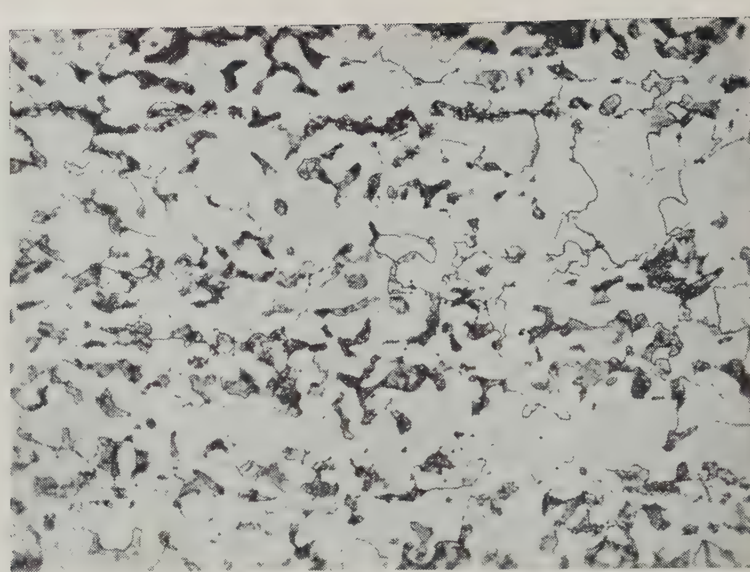
Sample	Composition, wt-% C	Mn	Si	S	P	Ni	Sn	Al
Bar stock	0·147	1·36	0·15	0·032	0·019	0·06	0·02	0·010
Abnormal sample	0·167	1·54	0·33	0·050	0·048	0·10	0·03	0·026

Controlled cooling experiments

If the abnormal structure resulted only from a difference in overall hardenability between normal and abnormal steel, it should be possible to produce roughly similar structures in both steels by adjusting their respective rates of cooling.

Small specimens were subjected to a wide range of cooling rates from 890°C and their temperatures were recorded continuously during experiments. The cooling rates at 815°C were determined and ranged from 950°C/min to 12°C/min. Normalizing is represented by the cooling rate 175°C/min.

1c *Abnormal structure after tempering for 1 h at 630°C, showing carbide precipitation in the second constituent* ×1500



Structure of an abnormal sample after annealing from 900°C ×500

In no case did the structure produced in the abnormal sample resemble any of those obtained from the normal sample. The mixture of pale-etching constituent and ferrite persisted at all cooling rates above 90°C/min except at 950°C/min when an as-quenched structure was formed. At rates of cooling below 90°C/min a mixture of ferrite and unresolved pearlite was formed, similar to that shown in Fig.1*d*.

Hardness results

The anomalous mechanical properties of the abnormal sample are well illustrated by hardness measurements made after controlled cooling as shown in Table II. After each treatment the abnormal sample was much harder than the normal one, the difference in hardness increasing from 38 points as slow-cooled to 70 points as quenched in boiling water. Additional measurements were made on a low-load hardness tester in an effort to discover the relative hardnesses of individual constituents of the microstructure: the results are shown in Table III.

Owing to its small particle size and dark colour it was not possible to make and measure hardness impressions on the second constituent in the sample cooled at 25°C/min. The results given in Table III represent the means of a large number of readings showing considerable scatter, so they must be considered as only approximate. The low-load hardness readings cannot be directly compared with the results of Vickers hardness tests at high loads but they serve as a useful comparison between samples. The great difference in hardness of the second constituents after normalizing (175°C/min) is particularly impressive; at the highest cooling rate the difference in hardness is less marked.

Soaking treatments at high temperatures

The results of chemical analysis indicated that the abnormal structure could not be attributed to any abnormality of the overall composition. On the other hand, the results of the hardenability tests suggested that the abnormal structure could be interpreted as the result of a microsegregation of Mn. If this were true it should be possible to remove the abnormal structure by reducing the extent of the microsegregation, either by hot-work or by soaking at high temperatures for long times.

Two samples of material with abnormal structure were sealed under vacuum in silica capsules and subjected to prolonged heating at temperatures near 1100°C and 1200°C respectively; the initial structure of these samples is shown in Fig.1*e*. After soaking, both samples were normalized in air from 890°C; the structure of the sample heated at 1100°C for 50 h was unaffected by the treatment; the structure of the sample heated at 1200°C for 40 h is illustrated in Fig.1*f*, and shows a normal distribution of ferrite and pearlite with a Vickers hardness of 162. Subsequent repeated normalizing treatments did not affect the structure of this sample.

Mechanical tests

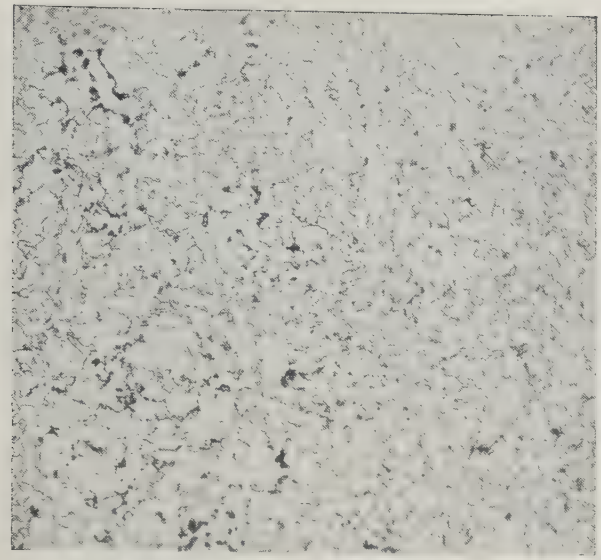
The abnormal structure has been found to be associated with an unusually high hardness in sections in the air-cooled condition. The results of the foregoing experiments suggested that this was probably due to the formation of martensite in the microstructure, and the possibility of abnormal material showing inferior impact resistance therefore caused some concern. A sample of material showing abnormal structure was cut into blanks from which small notched impact test-

TABLE II Hardness results; Vickers diamond hardness nos.: 5 kg load

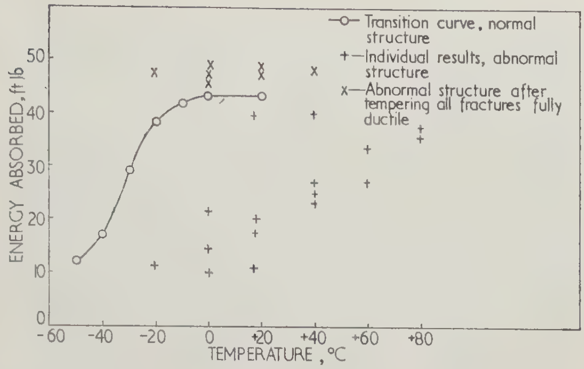
Condition	Abnormal sample	Bar stock
Slow-cooled from 890°C (25°C/min)	182	144
Normalized from 890°C (175°C/min)	204	147
Spray-cooled from 890°C (330°C/min)	232	171
Quenched from 890°C into boiling water (950°C/min)	299	229

TABLE III Hardness measurements; Vickers diamond hardness nos.: 5 g load

Condition Cooled from 890°C at	Abnormal sample		Bar stock	
	Matrix	Second constituent	Matrix	Second constituent
175°C/min	239	490	183	295
330°C/min	259	459	205	292
950°C/min	292	590	267	534

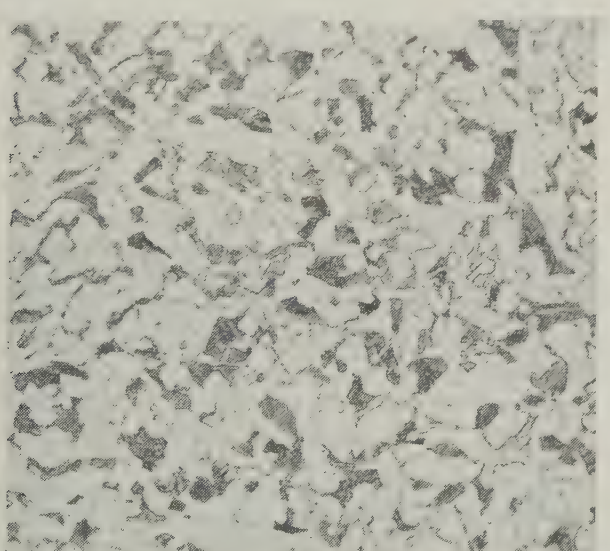


1 e *Initial abnormal structure of a* 1·5%Mn *steel* ×300



2 *Notched impact properties of abnormal samples, before and after tempering*

pieces could be prepared. The blanks were heated at the normalizing temperature and subjected to accelerated cooling at a rate just high enough to convert all the second constituent to martensite; the Vickers hardness of the treated blanks ranged from 197 to 206. Notched test-pieces prepared from these blanks, and from stock material with normal structure, were tested in impact over a range of temperature to determine the position of the ductile–brittle transition; in Fig.2 the energy absorbed to fracture is plotted against testing temperature. The results have considerable scatter but show that in specimens with abnormal structure, the transition is taking place at or above 20°C, a much higher temperature than for normal samples of 1·5%Mn steel. The remaining test-pieces were subjected to a 1 h tempering treatment at 630°C; the results of the subsequent impact tests are included in Fig.2. The tempering treatment caused a marked lowering of the transition temperature in every case and restored full ductility at room temperature.



1f *Structure of the sample shown in Fig.1(e) after soaking at 1200°C followed by normalizing, showing a normal distribution of ferrite and pearlite* ×300

DISCUSSION

Comprehensive chemical and spectrographic analysis of normal and abnormal samples of 1·5%Mn steel showed that there was no feature of the overall composition which could be responsible for the observed differences in structure. Tests conducted over a wide range of cooling rates from the normalizing temperature have revealed a marked difference in the response to heat treatment of normal and abnormal samples, which could be described as a difference in hardenability. Mechanical tests and tempering treatments have shown that the pale-etching constituent has properties resembling those of martensite. In particular, the excess hardness of abnormal samples was reduced by a conventional tempering treatment which restored notch ductility at room temperature and caused carbide precipitation in the martensite. Cooling at rates slower than normalizing in air caused the formation of fine pearlite having a distribution suggestive of interdendritic segregation. Although thin sections of 1·5%Mn steels of this type are recognized as being on the borderline of air hardenability, some further explanation is needed to account for the consistent formation of martensite in some samples and formation of pearlite in others over wide ranges of cooling rate. The work of Bain *et al.*[3] on extra-equilibrium constitution showed that microsegregation of manganese probably causes the replacement of pearlite by martensite.

According to earlier workers, such a segregation would persist, like that of phosphorus, to high temperatures in the austenitic range, and would require prolonged soaking at high temperatures for its dispersal. Manganese lowers the temperature of the A_3 transformation so that those regions rich in Mn would become enriched also in C by the ferrite formation in adjacent regions and transform to the appropriate extra-equilibrium constituents.

Bastien[6] has discussed the role of impurity elements in the formation of banded structures and has shown that the segregation of P in particular can encourage banding in pearlite–ferrite structures. Figure 1*d* shows banding developed by annealing and it appears likely that P (0·048%) has been responsible for this by its influence on C migration during transformation. However, it seems unlikely that this P content could be solely responsible for the development of the

abnormal structure by normalizing, since the structures of Figs.1*e* and 1*b* are clearly not banded. Abnormal structures have been observed also in a steel with 0·15%C and 1·66%Mn and with a P content as low as 0·024%.

Segregation arising during the solidification of the ingot should be largely eliminated by the subsequent soaking and hot-working processes. The work described in this paper indicates that complete elimination of segregation is not always achieved. One way in which this can occur is when large finishing sizes are rolled from small ingots, the material thus experiencing a minimum of hot-work and soaking. It is especially important in the case of 1·5%Mn steel that plate and bar of large section should be rolled from ingots of sufficiently large initial size.

SUMMARY AND CONCLUSIONS

It has been shown that the abnormal structure observed in some samples of 1·5%Mn mild steel arises from microsegregation of alloying elements, and most probably of Mn. The microsegregation was eliminated by prolonged soaking at 1200°C. In practice, microsegregation arises during solidification of the ingot[4] and persists owing to inadequate hot-working and soaking: efforts should be made to avoid this trouble by beginning with ingots of sufficiently large size. The probability of obtaining abnormal structures in the presence of microsegregation is reduced by keeping the C and Mn contents somewhat below the upper limits specified for this steel in BS.2772: Part 2[1]: this is especially true of the Mn content.

The abnormal structure, consisting of a pale-etching constituent in a ferrite matrix, has an unusually high hardness and is associated with notch-brittle behaviour at room temperature. The excess hardness and the notch brittleness are both removed by a conventional tempering treatment for 1 h at 630°C. The properties of the pale-etching constituent and its response to heat treatment are consistent with the view that it is a form of martensite; it is deduced that it occurs in small regions whose hardenability has been increased considerably by segregation.

Soaking finished components at 1200°C to eliminate microsegregation is impractical, but tempering at 630°C after normalizing is a convenient corrective treatment for the abnormal structure and properties occurring in some samples of 1·5%Mn mild steel to BS.2772: Part 2.[1]

ACKNOWLEDGMENTS

The author wishes to acknowledge the assistance of Messrs J. Smith and J. Deakin who together performed the bulk of the experimental work in this paper.

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The influence of three foreign cations on the reduction of magnetite

V. J. Moran and A. E. Jenkins

SYNOPSIS

Microscopy has been used in a study of the influence of small concentrations of boron, chromium, and aluminium during the solid state reaction between iron and magnetite. The information obtained has been used in turn to study the controlling processes in the hydrogen reduction of magnetite. 1960

INTRODUCTION

The reduction of an oxide of iron proceeds with the intermediate formation of lower oxides which are stable at the temperature of the operation. Practical cases range in complexity from that where magnetite is reduced at temperatures below 560°C, with no intermediate oxide, to that where hematite is reduced at temperatures above 560°C, forming both magnetite and wüstite. The overall processes and some of the sub-processes have been studied by Edström[1] who gives an exhaustive bibliography.

The most important practical case is that of the reduction of magnetite at temperatures above 560°C with the formation of wüstite and iron. The step hematite to magnetite, which is excluded here, is of less interest because the thermodynamic driving force is of a low order and the differences in the crystal structure of magnetite and hematite are such as tend

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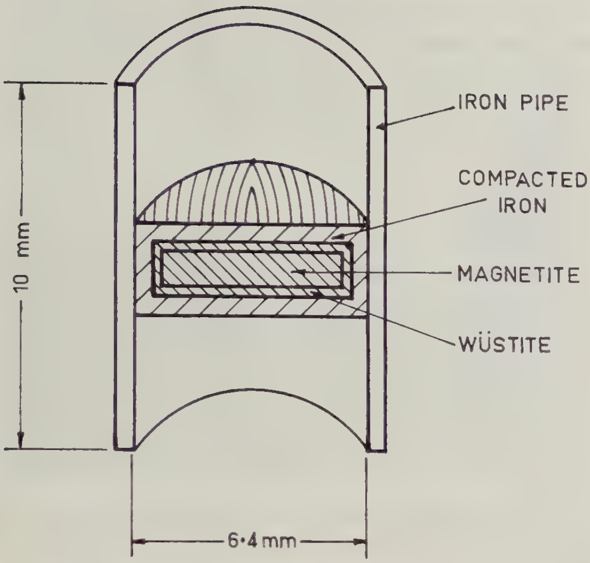
When this paper was written Mr Moran, who is at present with the University of Sheffield, was at the University of New South Wales, Australia, where Professor Jenkins is associate professor in charge of metallurgical engineering,



1 *Section of magnetite–iron specimen*

to yield non-continuous layers in which control by transport processes is unlikely to be significant.

Edström has used a model, proposed by Hauffe for the oxidation of iron, to analyse the reduction mechanism of hematite. The overall process in the reduction of an hypothetical pure single crystal of magnetite where wüstite and iron layers are formed may be pictured as composed of interfacial and mass transfer sub-processes as follows:

(*a*) At the gas/wüstite interface oxygen ions are abstracted from the lattice by a reaction or sequence of reactions whose net effect is

$Fe_xO + H_2 \rightarrow H_2O + xFe$

or

$Fe_xO + CO \rightarrow CO_2 + xFe$

leaving the wüstite supersaturated with regard to iron which nucleates on the wüstite surface and continues (if the lattice from which the nuclei are produced is perfect) to grow as columnar crystals by the continuous supply of iron to their base.

(*b*) At the wüstite/magnetite interface some iron ions change their charge and situation in the interstices of the oxygen lattice, producing, with the addition of iron supplied by the transport process (d), an interfacial reaction which may be written

$Fe_3O_4 + Fe \rightarrow 4FeO$

(*c*) Mass transfer involving reducing gas molecules or ions inward, and reduction product gases outward, occurs in the spaces between the columnar crystals of iron and through a static gas layer at the external surface of the iron.

(*d*) Ferrous ions and electrons are transferred by a vacancy mechanism across the wüstite.

It should be emphasized that the above is a statement of the essentials of the process only. There are a number of side sub-processes, some of which are understood and some incompletely understood. Included among these are the formation of activated complexes during the reactions of (a) above; the consequences of solution of oxygen, carbon, and hydrogen in the iron and the fissuring and recrystallization of the iron. These have been discussed in earlier papers and have no vital bearing here.

Recent papers by McKewan[2] and Quets *et al.*[3] have directed attention to the identification of the controlling subprocess in the reduction of magnetite and they have concluded that for the materials examined by them it is the interfacial gas/wüstite reaction which limits the rate of the overall process. The purpose of the present work is to examine the influence of small concentrations of some impurities on characteristic behaviour, namely aluminium, chromium, and boron, on the mechanism of magnetite reduction. Using synthetic magnetite pellets, the solid state magnetite–iron and the magnetite–hydrogen reductions have been studied independently.

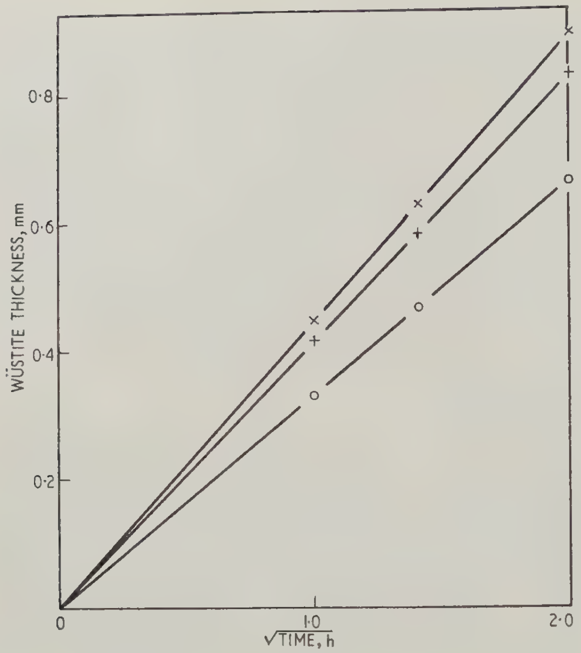
EXPERIMENTAL

Pure magnetite pellets, which were used throughout as blanks and to confirm results of previous workers, were prepared by pressing hematite powder and equilibrating for 40 h under a CO/CO_2 atmosphere at 1250°C. The method has been used by Smiltens[4] and Gorter[5] and involves a step-wise cooling under varying oxygen potentials to produce a stress-free compact having an Fe (total)/Fe^{++} ratio of three. Controlled amounts of the impurities as Al_2O_3, Cr_2O_3, and B_2O_3 were added to the hematite by grinding the finely divided powders under ether in an agate mortar or by co-precipitation from aqueous solution. The hematite used was prepared from pure iron, by solution in nitric acid and precipitation with distilled ammonia. The pellets, after firing, were 5·08 mm dia. by about 2·3 mm.

The value of the Fe (total)/Fe^{++} ratio was determined by chemical analysis of each batch of pellets using a silver reductor and titrating with standard ceric sulphate solution which was standardized daily against arsenious oxide. The limits of accuracy of the determination of the ratio are estimated to be $\pm 0{\cdot}03$ at the ratio three and in all cases the value was found to be within these limits.

The iron–magnetite reaction was effected by pressing carbonyl iron powder around the magnetite pellet in a piece of iron pipe 10 mm long by 6·4 mm bore. After heating for the required time in a tube furnace under an argon atmosphere and quenching in water, the tube and the iron magnetite compact were cut in halves, the two halves of the reacted iron–magnetite compact being broken out and mounted for polishing. Figure 1 shows a section of the specimen, the cross-hatched portion being that which was mounted.

Hydrogen reduction was carried out by placing the pellets singly or in sets up to six in an alumina boat in a tube furnace of 12 mm bore. After placing the boat in the furnace at temperature, the system was allowed to come to equilibrium during a period of 5 min under argon. Hydrogen was admitted at 880 cm^3/min, which was established to be greater than the critical flow rate at the highest temperature used, for varied times after which the boat was pushed to an extension of the furnace and allowed to cool under argon. The loss of oxygen was determined by weighing before and after reduction. Reduced pellets were mounted in bakelite and cut back by normal grinding on coarse wet papers until a plane containing the central axis and a diameter was exposed (i.e. the same plane as is exposed in the magnetite–iron specimens).



+ Pure Fe_3O_4
× 1 cat-%B
○ 1 cat-%Cr

2 *Growth of wüstite, with square root of time at 900°C*

After polishing and etching in 2N HCl where necessary, both types of specimens were examined metallographically and the thickness of the various reacted layers measured. In the case of the iron-reacted specimens of low impurity content the measurement was simple and exact, since all phases were dense and the boundaries clearly defined. In some specimens the reacted layer was not of uniform thickness around the perimeter of the section examined. Poor contact between iron and magnetite may have slowed the reaction; in other cases transverse pressing cracks in the magnetite had arrested the reaction on one side. The thickness recorded was that of the thickest uniform layer remote from the corners, since all probable sources of error other than corner effects are negative. Porosity was not found to be a source of error, though its presence introduces the possibility of surface and vapour-phase diffusion. The density of most specimens closely approached the theoretical value, but even when some porosity was visible under the microscope there was no significant change of wüstite thickness in the vicinity of this porosity. Much of the visible porosity, which appears as black fields in the micrographs, is thought to result from faults in the polishing technique, for which no cure has yet been found. The accuracy of these measurements was of the order ±0·015 mm.

In the hydrogen-reduced, and some of the higher impurity iron-reacted specimens, the accuracy of measurements was of a lower order since the phase boundaries were not always clearly defined. Synthetic magnetite single crystals were also used. These were made by hydrothermal synthesis in a silver-lined bomb, using sodium hydroxide solution. They were generally too small (1–2 mm) for accurate measurement of rates and were used only as a check on the microstructures obtained in polycrystalline materials.

RESULTS AND DISCUSSION

Solid state reaction

Considering first the solid state reaction of iron with magnetite, the effect of foreign cations originally present in the magnetite may be anticipated to be as follows:

Soluble ions

Cations which are soluble in wüstite will be retained in the wüstite layer and, depending upon their valency, may tend to alter the concentration of vacant sites via which the transport of ferrous ions in wüstite occurs. In the present case, divalent ions may be expected to have no effect, while trivalent ions may cause an increase and monovalent ions a decrease in the number of vacancies. Hauffe[6] discusses a mechanism of this sort which applies when the transport of nickel ions in nickel oxide is varied by additions of chromium or lithium.

Referring to the data of Fig.2 and making use of the parabolic rate constant k where

$$k=(\Delta x/t)^2 \qquad (1)$$

Δx being the thickness of wüstite formed by reaction of iron with magnetite in time t, the value for the pure oxide at 900°C is $1{\cdot}76\times10^{-3}$ cm²/h. When progressive small additions of boron are made to magnetite and these pellets are reacted with iron at 900°C, the plot $(\Delta x/t)^2$ remains linear and the value of k increases with additions up to about 1·2 cat-%B. The 1% boron line at 900°C is shown in Fig.2, the value of k being $1{\cdot}99\times10^{-3}$ cm²/h.

Transport of iron in wüstite is considered to occur by counter diffusion of ferrous ions, Fe^{++}, and ferrous ion vacancies, $Fe''_{\square}$, and it has been assumed that there are two ferric ions or electrol holes, $\oplus$, for each such vacancy. In these terms the transport process is usually written

$$Fe^{++}+2e+(Fe''_{\square}+2\oplus)_{FeO}=0 \qquad (2)$$

If equilibrium compositions are assumed, the numbers of $Fe''_{\square}$ in pure wüstite at 900°C at the magnetite and iron interfaces, calculated from the terminals of the wüstite field in the phase diagram, are respectively 12 and 5% of the ferrous ion sites. The vacancy gradient is thus 7% and the average number of vacancies 8·5%. When 1 cat-% of foreign trivalent ions is included in the structure, the average number of vacancies will rise to 9%, if these ions are assumed to act only as additional electron holes and the gradient of vacancies remains unaltered.

Hauffe has assumed for the case of chromium ions in nickel oxide that the values of k (equation (1)) are about proportional to the numbers of vacancies in the pure and impure oxide. Thus in the present case

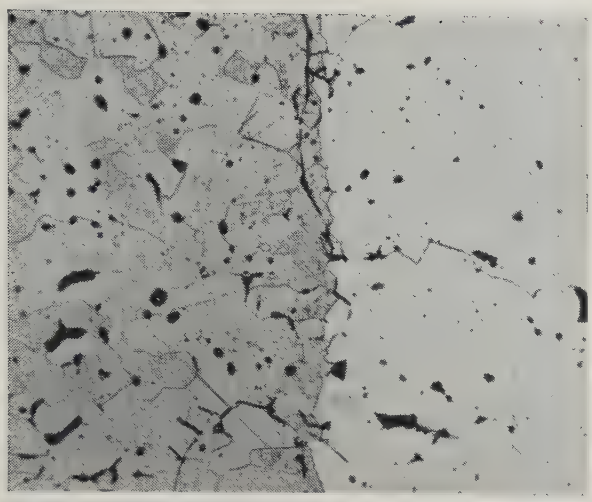
$$\frac{k}{k^o}\simeq\frac{C}{C^o}\simeq\frac{9{\cdot}0}{8{\cdot}5}=1{\cdot}06 \qquad (3)$$

and

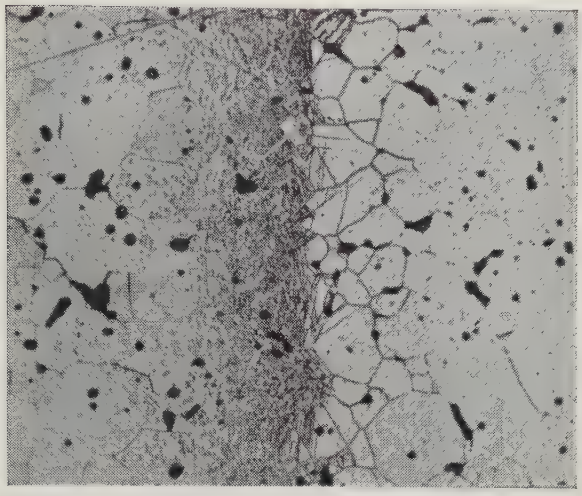
$$k\simeq1{\cdot}76\times10^{-3}\times1{\cdot}06=1{\cdot}87\times10^{-3}$$

where C is the average concentration of vacancies and the superscript ^{o} indicates the pure oxide. Agreement between the observed and calculated values is poor and it would in fact be surprising if more than qualitative agreement were obtained within the assumptions made.

The cases discussed by Hauffe and the present one are by no means analogous, for here the values of C are averages over a wide range and the original



3 *Magnetite reacted with iron at 900°C showing the magnetite/wüstite interface, etched* ×250



4 *Magnetite with 1 cat-%Cr reacted with iron at 900°C showing the magnetite/wüstite interface, etched* ×250

concentration of vacancies is large in proportion to those which might be expected to result from the presence of an impurity.

The experimental procedure imposes upon the starting material a fixed oxygen potential which determines the number of interstices in the oxygen lattice that will be occupied by ferrous and ferric ions. Upon reduction, the boundary conditions of the diffusion system in wüstite are set by the existence of an interface with magnetite on one side and by the presence of iron on the other. The concentrations of vacancies mentioned above are thus calculated on the assumption that the wüstite at these interfaces will have the equilibirum composition. In the presence of an impurity, it is possible that the cation–anion ratios in the starting magnetite, which is brought to equilibrium with an atmosphere of the same oxygen potential as before, may differ from those in pure magnetite. It is considered, however, that the contribution of this variable to the effects observed will be insignificant.

An explanation of the discrepancy may lie in a recent study of the wüstite structure by Roth[7] who has pointed out that the vacancies in wüstite are associated with tetrahedrally co-ordinated iron ions, are clustered, and may be regarded as subnuclei of magnetite. Thus it is possible that boron, with its strong tendency toward low co-ordination with oxygen, may tend further to stabilize such nuclei, causing the formation of more than one half-vacancy per boron ion expected from considerations purely of electrical neutrality.

The addition of boron to magnetite causes an increase in the grain size of the pellets. The size increases from about 0·035 mm, the size observed in all other pellets used in this work, to about 0·50 mm at 1 cat-%B. A slight anisotropy of growth is observed in these larger crystals, the wüstite growth being greater in some than in others in the same specimen, but, although the accuracy of measurement of the layer thickness is adversely affected, it is not considered that the change in wüstite thickness observed in the presence of boron is due to the larger grain size. In fact, it is suggested that the larger grain size should slow, rather than accelerate, the wüstite growth, since the presence of grain boundaries provides areas of high energy in which ferrous ion mobility would be high.

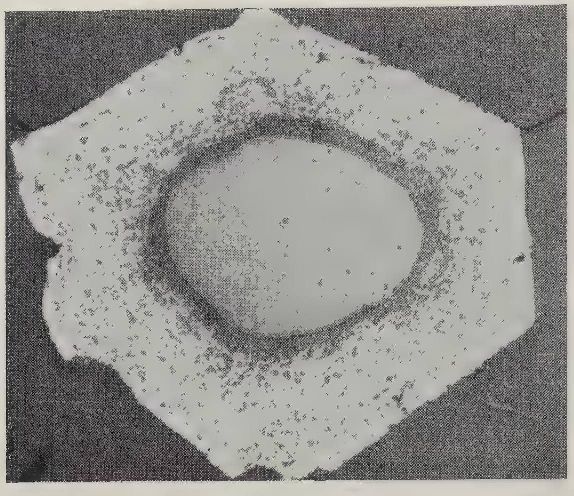
It might be expected that the operation of a mechanism such as that described could be confirmed by the addition of small concentrations of a monovalent ion. Unfortunately, however, the relatively large ionic radius and tendency to high volatility in the group I metals makes it difficult to obtain magnetite pellets having a homogeneous distribution of impurity by the experimental technique used. Further, in the absence of data on the solubility of such ions in wüstite, it is impossible to distinguish a rate *diminishing* process of this sort from that to be discussed in what follows.

Insoluble ions

When progressive additions of aluminium and chromium ions are made, a diminution of rate in the solid state reaction is found which is evidently of a different order to that observed with boron. The 1 cat-% line for chromium is shown in Fig.2. The value of k (equation (1)) is $1{\cdot}11\times10^{-3}$ cm²/h and an identical value is obtained for 1 cat-%Al. The reaction is further characterized in the presence of these elements by a tendency for preferential reaction along the magnetite grain boundaries, which may be observed by comparison of Figs.3 and 4. When the chromium content is progressively raised above 1 cat-%, the thickness of the wüstite layer, determined at, say, 2 h, diminishes further and approaches zero at about 8%, although a grain boundary net of wüstite extends into the pellet to about two-thirds of the penetration expected of pure magnetite.

In examining the reason for this behaviour, the following evidence is assessed:

Aluminium is substantially insoluble in wüstite. This information comes from McIntosh *et al.*[8] and the identity of behaviour of chromium leads to the assumption that it also is insoluble. However, there is, in the present data, some barely significant evidence that small concentrations of aluminium, at about 0·05 cat-%, increase the rate of wüstite formation. Thus, apart from very low concentrations, it seems improbable that the influence of these ions is exercised through the defect structure of wüstite.



5 *Pure magnetite single crystal reduced in hydrogen at 900°C showing magnetite, wüstite, and iron, etched* ×100

Aluminium diffuses more rapidly in magnetite than does chromium. This might be inferred from the radii of the two ions but direct evidence comes from the observation that a much longer soaking time is required to produce a homogeneous spinel pellet from mixed powders of chromic oxide and hematite than from mixtures where the impurity is alumina. This effectively rules out the possibility that the change of rate is due to the imposition of a new controlling process, namely, the diffusion of insoluble impurities in the magnetite ahead of the interface.

The plot of wüstite thickness against the square root of time remains linear. At concentrations of the impurity greater than 1 cat-%, accurate measurement of wüstite thickness is difficult because of the increasingly diffuse nature of the interface, but at 1 cat-% the accuracy is estimated to be ±0·017 mm and the plot is linear at times up to 8 h. The process therefore is not controlled, nor is its control modulated, by an interfacial reaction.

With these possibilities excluded, there remains the inference that the diffusion of iron in wüstite is interfered with by the presence of an insoluble phase. In the case of aluminium, this is presumably $3FeO.Al_2O_3$, the insoluble phase identified by McIntosh. The phase is not visible in the microstructure of wüstite nor is this expected since the dispersion would need to be submicroscopic to account for the observed effect.

With diffusion in the bulk of the grains thus relatively restricted, mass transfer occurs more or less normally at grain boundaries. Fully or partly surrounded grains are subject to stress or actual shear by the small volume change due to the transformation, providing new free surfaces, or planes of high energy within the grain, along which transformation again proceeds.

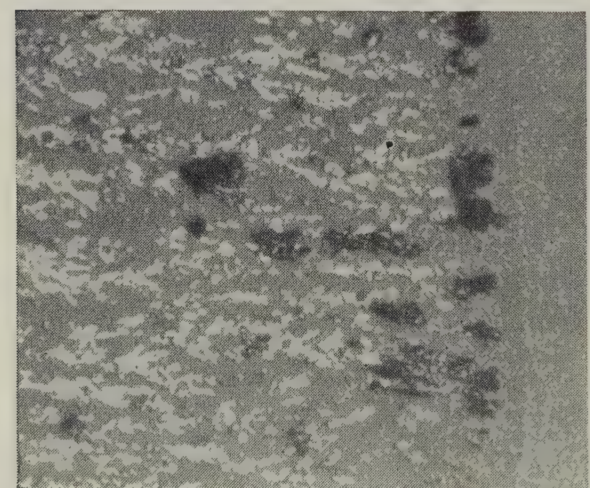
Hydrogen reduction

The ability to vary the apparent mobility of ferrous ions, and through it the rate of the solid state reaction, provides a useful tool in the study of the controlling process during the gaseous reduction of magnetite.

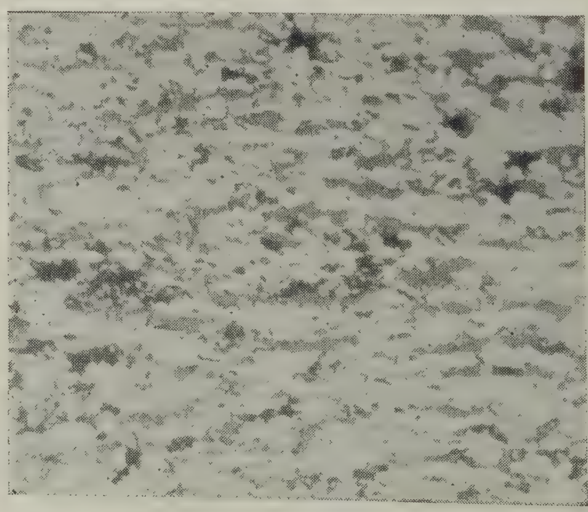
Pure magnetite

It has been assumed that when magnetite is reduced with hydrogen in the temperature range 400–1000°C the reactions proceed by the formation of discrete layers of the reaction products. An important exception to this mechanism, which has been disregarded by Quets,[3] occurs in the range from about 900°C down to the temperature at which wüstite becomes unstable. Here a substantial retention of wüstite in the iron layer occurs which is similar to that shown in some of the photomicrographs of Edström.[9] The amount of retention is relatively small at 900°C, but is observed to increase down to 700°C where as much as 50% of a field in the 'iron' layer is wüstite. Figure 5 shows a synthetic magnetite single crystal reduced in hydrogen at 900°C. Retained wüstite in the reacted layer is clearly visible. Figures 6 and 7 show structures of the reacted layer when a pure magnetite compact is reduced at 700°C for 35 min, Fig.6 being at the reacted layer/magnetite interface and Fig.7 near the outside surface of the specimen.

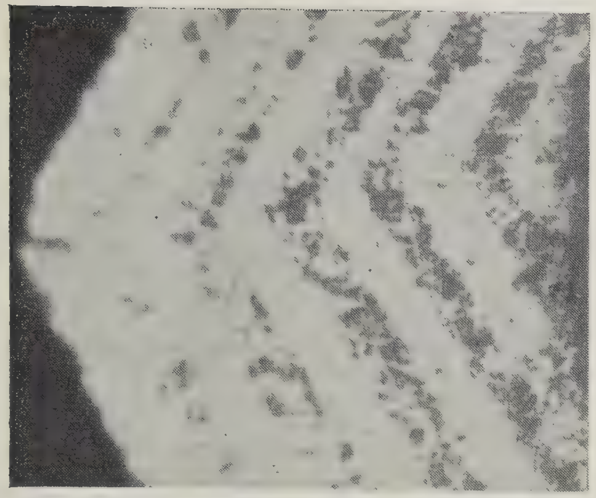
In Fig.5 some evidence of a layer structure in the reacted region is visible and this is observed to a greater or less extent in both single crystal and polycrystalline magnetites after reduction. A pronounced



6 *Pure magnetite compact reduced in hydrogen at 700°C showing the reacted layer containing iron and wüstite at the interface, unetched* ×1000



7 *Same as Fig.8, but near outside of specimen, unetched* ×1000



8 *Pure magnetite single crystal reduced in hydrogen at 700°C showing banded structure of iron and wüstite, unetched* ×1000

example of layering is seen in the single crystal of Fig.8 which has been reduced at 700°C.

It is suggested that the model for the formation of iron in this temperature range will contain some elements of the following steps:

(i) at first oxygen ions are abstracted from the outside of the magnetite lattice, making a few molecular layers of wüstite

(ii) oxygen continues to be abstracted from the wüstite and because, at the free surface, supersaturation with regard to iron occurs, iron ions diffuse inward, causing a widening of the wüstite layer

(iii) however, supersaturation at the free surface and diffusion inward unbalance after a short time and iron nucleates at the free oxide surface (or in cracks or at grain boundaries). These nuclei grow inward

(iv) since the precipitation of iron from wüstite involves a large volume change, the crystals of iron will be porous, perhaps dendritic

(v) the crystals act now as conduits bringing in hydrogen, their tips becoming the new 'outside' of the specimen and the cycle starts again, this time at step (ii)

(vi) as the reduction proceeds, the bases of these crystals widen out, since attack is also occurring at the walls of the conduits.

A process of this complexity defies adequate mathematical treatment and it is evident that no single controlling process can be defined. At 700°C the increase in reacted layer thickness, as measured by microscope, is found to be parabolic with time, rather than linear, passing through zero thickness at a finite time. This, of course, suggests an element of diffusion control but the total weight loss also contains the element due to reaction at the iron crystal walls. Weight loss data, as might be expected from the nature of the structure at this temperature, are scattered and it is not possible to determine whether additions of chromium or aluminium have an effect on the reduction.

As the temperature of reduction is raised from 700 to 900°C, the retained wüstite becomes progressively coarser and its amount less. Figure 9 shows a field in a pure magnetite compact after reduction at 900°C for 10 min. The structure is essentially similar to that of the single crystal in Fig.5, containing islands of wüstite which diminish in size towards the outside of the specimen.

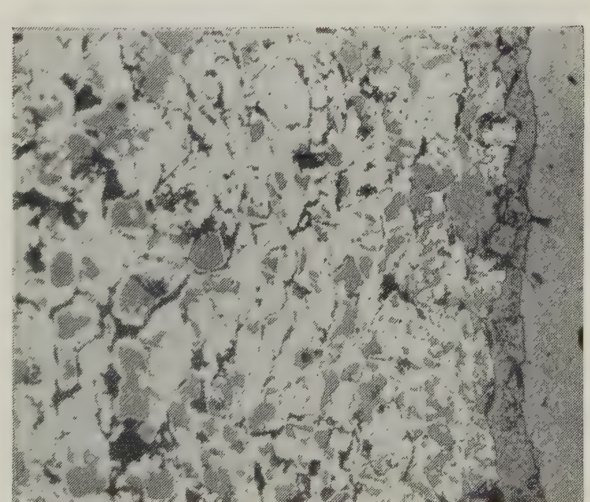
Chromium magnetite

When specimens containing 1 cat-%Cr are reduced under the same conditions, islands of similar size are surrounded but they retain their identity further back into the reacted layer and a decrease in the weight loss of about 10% results. The effect is illustrated in Fig.10.

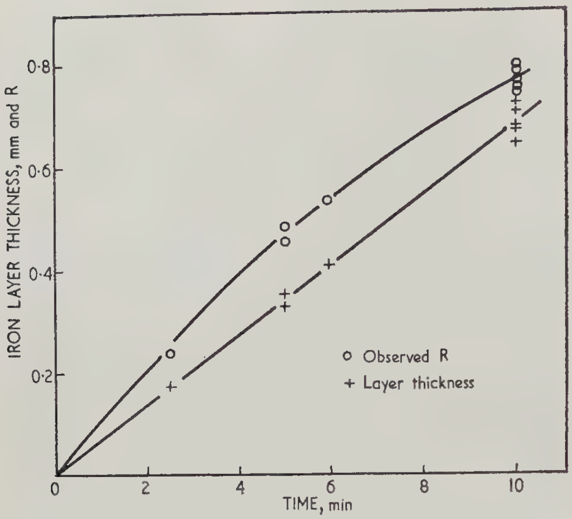
In polycrystalline specimens the first precipitation of iron tends to occur at grain boundaries and in the case of chromium magnetite this tendency is presumably enhanced by the preferential formation of wüstite in these regions, as discussed in an earlier section. However, the presence of grain boundaries is not essential to the retention of wüstite at 900°C as is shown by its occurrence in the single crystal of Fig.5.

It is therefore apparent that, although the thickness

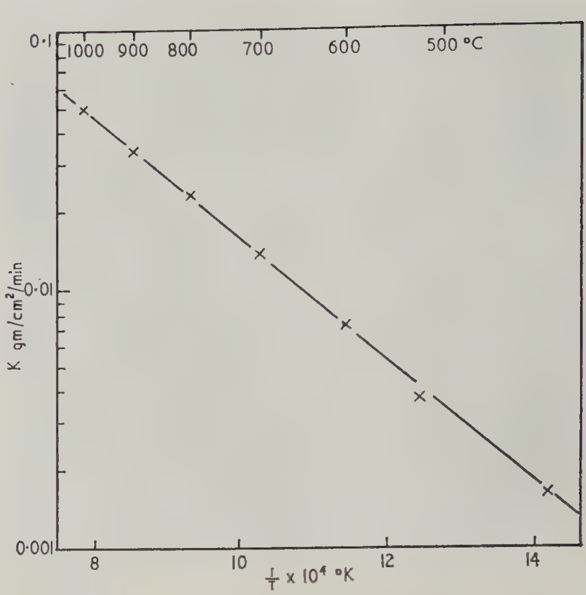
9 *Pure magnetite compact reduced in hydrogen at 900°C showing wüstite retained in the reacted layer, etched* ×250



10 *Magnetite with 1 cat-%Cr reduced in hydrogen at 900°C showing wüstite retained in the reacted layer, etched* ×250



11 *Reduction ratio and reacted layer thickness with time during hydrogen reduction of boron–magnetite at 900°C*



13 *Log* K *against reciprocal absolute temp. for 1 cat-%*B *magnetite*

of the reacted layer at 900°C may depend upon another factor to be examined below, that part of the weight loss which results from the reduction of retained wüstite is sensitive to, and controlled by, the rate of solid state diffusion in iron.

At 1000°C wüstite is not retained to any significant extent in either pure or chromium magnetites.

Boron–magnetite

The addition of 1 cat-%B to magnetite increases the mobility of ferrous ions and causes the reduction to occur in discrete layers at all temperatures between 400° and 1000°C. The absence of wüstite in the iron layer, and of the element of solid state diffusion control which its presence implies, makes it possible to calculate significant rate constants throughout this temperature range.

Figure 11 shows results obtained when magnetite compacts containing 1 cat-%B are reduced at 900°C. McKewan has used a relationship which gives the ratio of the thickness p, of the reacted layer to the original radius of a sphere r_0, in terms of R, the ratio of oxygen removed to that originally present. It can be shown that, for discs or pellets of the dimensions used in the present work, an appropriate relation is

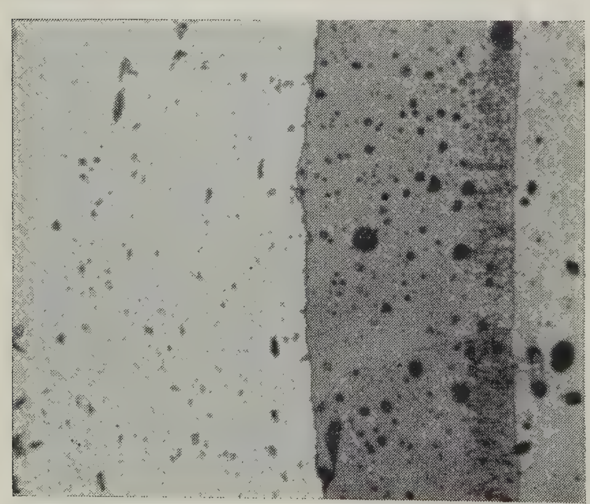
$$p/r_o = 1-(1-R)^{0\cdot42} \quad \ldots\ldots (4)$$

where $r_0 = 0\cdot145$ cm and is a dimension characteristic of the pellets. From this the rate equation for short cylindrical pellets is

$$r_0 d_0 \, [1-(1-R)^{0\cdot42}] = Kt \quad \ldots\ldots (5)$$

where K is the rate constant, t the time in minutes, and d_0 is the original density, which, for the specimens used, is 5·13.

In Fig.11 the points (crosses and circles) are experimentally determined values. The lower line is the straight line of closest fit to the values of layer thickness observed and the upper curve is calculated by equation (4) from this straight line. The agreement between the calculated line for R and the experimental points may be taken as a check in the present context of the validity of McKewan's equation. Thus, where a reduction is proceeding by means of an interface whose geometrical relationship with the original may be clearly defined as in equation (4), it is possible to use either p or R to determine a rate constant. But where the interface is not well defined, as in the previous cases discussed, equation (5) becomes meaningless.



Fe $\qquad$ Fe_xO $\qquad$ Fe_3O_4

12 *Magnetite with 1 cat-%*B *reduced in hydrogen at 900°C showing discrete reaction product layers, etched* ×250

The structure of a boron magnetite pellet reduced for 10 min at 900°C is shown in Fig.12. The presence of a thick and clearly defined layer of wüstite and the absence of wüstite in the iron layer is characteristic. The wüstite layer at 900°C is much thicker than the corresponding, although less clearly defined, layer in pure magnetite.

At lower temperatures the wüstite layer becomes thinner and has completely disappeared at 600°C but at no stage is there a retention of oxide within the iron layer. The disappearance of wüstite at a lower temperature is substantially in accordance with the iron–oxygen equilibrium phase diagram. Below this temperature the reaction product consists simply of a layer of porous iron.

In Fig.13 a plot of log K (equation (5)) against reciprocal temperature is shown for boron magnetite. Activation energy from the slope of this line is $-11\,000$ cal.

The controlling process in the reduction of boron-magnetite in the region where wüstite is stable is the interfacial reaction between hydrogen and wüstite and in the lower range it is the similar reaction between hydrogen and magnetite. This is established from the linear plot of reacted layer thickness with time (Fig.11), from the microstructures and from the value of the activation energy recorded. McKewan has suggested that the existence of a wüstite layer during reduction is evidence that solid state diffusion of iron is not controlling during gaseous reduction at elevated temperature. Indeed, the thickness of this layer in the region where wüstite is stable may be taken as a measure of the latitude existing between control by the gas–solid or solid state diffusion process. The possibility of control by diffusion of iron in wüstite is further excluded by the different order of activation energy for the solid state reaction, in this work found to be $-40\,000$ cal from the value of the parabolic rate constant (equation (1)) for the pure oxide already quoted and the additional values determined at 1000° and 800°C, which are $6{\cdot}9\times10^{-3}$ and $0{\cdot}27\times10^{-3}$ cm²/h. It has been pointed out by Edström that this activation energy is not a true one, since the concentration difference across a wüstite layer varies with temperature, but it is a valid criterion here since the consequences of variation apply in both cases.

The data of Fig.13 indicate that the activation energy for the removal of an oxygen ion from a surface site in a wüstite lattice by hydrogen is little, if at all, different from that to effect the same removal from a magnetite lattice, an expected result. The rate constants for the hydrogen reduction of pure magnetite in the regions where these can be calculated (430–600° and 900–1000°C) are insignificantly different from those for boron magnetite and the activation energy is identical.

CONCLUSIONS

1. The rate of the solid state diffusion of ferrous ions in wüstite is increased by the presence of trivalent ions which are soluble in wüstite.
2. The rate is decreased when trivalent ions which are insoluble are present.
3. In the hydrogen reduction of magnetite, the controlling processes are more complex than has formerly been accepted. In pure magnetite reduced at temperatures above 900°C, the controlling process is mainly that at the hydrogen wüstite interface. As the temperature of reduction is lowered to 700°C, this control is increasingly interfered with by control through the diffusion of iron in wüstite.
4. When boron is added to magnetite, the reduction proceeds with the formation of discrete layers of reaction products throughout the temperature range 430–1000°C and accurate rate constants can be determined at all temperatures.
5. The activation energy for the removal of oxygen from wüstite is found to be similar to that for the removal of oxygen from magnetite.

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The high-temperature Cowper stove

D. Petit

SYNOPSIS

Increasing attention is now being given to the problems arising from the demand for higher blast temperatures. The author discusses these problems in relation to the operation of a Cowper stove. He proposes solutions that are based upon a survey of methods used both in Europe and America; no single solution is possible, the one chosen will depend upon local circumstances and present developments. Changing demand in stove installation necessitates foresight if premature obsolescence is to be avoided. 1983

During recent years there has been much progress in blast-furnace operation. In this paper only one aspect is considered, that relating to stoves. Briefly, the position is this: operators demand increasingly higher blast temperatures; and the calorific value of the gas tends to diminish. Some figures will give a measure of the importance of the problems and the difficulties which have to be solved.

Temperature of the blast

Different plants have in the past operated at various blast temperatures depending on furnace conditions. For example, a large furnace in Lorraine used to consider 800°C as normal and 900°C as high. Three years ago the operators demanded 925°C at the bustle and a year ago 1000°C had already been achieved. Now 1050° and if possible 1170°C is demanded for normal basic iron production. For small furnaces making foundry iron or ferromanganese, temperatures of 1200° or even 1300°C are envisaged. Generally speaking these very high temperatures are required to anticipate the injection of oil or natural gas into the tuyeres; this tendency is world-wide. US practice is rapidly changing: the normal 600–700°C of a few years ago is giving place to 1000°C for large furnaces.

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The author is with the Société de Technique Industrielle, Paris.

While not all furnaces achieve this today, these are the temperatures demanded from stove builders for new installations.

HIGH-TEMPERATURE STOVES: THE PROBLEM AND ITS SOLUTION, WITH EXAMPLES

As stove performance is an extremely complex subject, for clarity, stoves of well defined dimensions will be considered wherever possible. These will be of typical modern stoves, most of which have reasonably similar dimensions and performance. For different requirements the dimensions can easily be modified to meet the situation.

To consider the characteristics of stoves it has been adequate to study existing design and performance data. These designs were based on studies and calculations made with the help of leading experts. For example, the checker-work calculations are based on Professor Schack's methods, and the results are as accurate as today's technical knowledge will allow.

Blast-furnace size and amount of wind blown

Most recent inquiries concern furnaces which burn 1200 tons* coke/d. With 117000 ft^3 (3300 m^3) of blast/ton of coke, this corresponds to a wind rate of 97000 ft^3/min (165000 m^3/h). While this figure cannot be expected to apply universally, it has been the basis for calculation for the last 10 or 15 years without major objection being raised. Incidentally this wind volume of 117000 ft^3/ton includes a margin for leaks but is assumed to be the volume of blast passing the stoves.

Temperature of cold blast

With the older gas engines, 40°C is generally assumed, but modern blowers at today's pressures frequently give 75–120°C. This influences stove performance and its effects will be discussed. In view of the long life of stove and stove equipment, it is essential to plan for the future. It is therefore prudent to provide for these high temperatures in advance.

Calorific value of blast-furnace gas

Furnaces producing basic iron from Lorraine ores normally produced a gas with a calorific value of 100–106 Btu/ft^3 (900–950 cal/m^3); some indeed still do. Sintering these low-grade ores has led to a reduction to 95 Btu/ft^3 (850 cal/m^3) and 90 Btu/ft^3 (800 cal/m^3) can soon be expected. Plants on high-grade ores with burden preparation and sintering are expected to produce a gas of 84 Btu/ft^3 (750 cal/m^3) or even 78 Btu/ft^3 (700 cal/m^3).

In the present state of knowledge the use of oil or gas at the tuyeres will not change these figures a great deal. The use of oxygen-enriched blast would increase them but its use is not yet established. Certainly all stove research in France today is based on a calorific value of 90 Btu/ft^3 (800 cal/m^3), and the solutions proposed in this paper would accommodate even leaner gas.

Solution to this problem

Many solutions are possible; the one chosen will depend on local circumstances and the results obtained from the active developments at present in progress. For this reason a single solution will not be presented, but rather a survey of possible methods, with a discussion of their merits and disadvantages, largely in terms of the position in Europe and, in particular, France. There has been more development in stoves in France than in the USA, probably because there is a lower demand for high temperatures in the USA, and because power is less expensive there.

Temperature of hot blast

The relation between the calorific value of the gas and the calculated flame temperature is first established. The next consideration is how to obtain blast temperatures of 1050°C in the bustle main after allowing a 70°C drop from the stove. This temperature drop is due to heat losses from pipes and valves. Temperatures of 1200° or even 1300°C are also considered.

Blast pressure

Although many furnaces are designed to operate at about 3 atm pressure, most inquiries relate to about 1 atm operating pressure in the stove. Pressure has little effect on the results obtained and creates no particular problem.

Calorific value, gas composition, dust content

All calculations presented are based on gas with a calorific value of 90 Btu/ft^3 (800 cal/m^3) with typically the following composition: 13·6%CO_2, 25%CO, 1·4%H_2, 60%N_2. It is assumed the gas has a dust content of 0·009 gr/ft^3 (20 mg/m^3) and that it is saturated with water at its working temperature at the inlet to the burner or preheater.

Possible additions of steam, oxygen, oil, or natural gas

These are not considered in detail because they all tend to increase the calorific value of the gas and therefore reduce any difficulty in achieving high blast temperatures.

Frequency of stove changes and possibility of heat storage

The possibility of using stoves as 'free gas holders' has been of considerable interest in the past.* With blast temperature around 800°C this was and still remains useful, particularly at weekends, but with modern stoves operating so close to the limit of the refractories this method of heat storage cannot now be used.

The length of time a stove is on blast is important in this respect. With older installations without mechanized valve control operating at around 600°C, blast periods of 1½ h or even 2 h are possible. In Europe, and especially France, they were 1 h. Because of the high temperatures and the problem of protecting the refractories, most modern installations are now based on ½ h blast periods, which for a given blast temperature obviously leads to a reduction in the maximum temperature of the refractories. Some experts are also of the opinion that this practice, because it leads to the minimum variations in expansion, favours longer refractory life. Against this must be considered the heat losses from decompression and a certain loss of flexibility in the installations because there is no longer, to the same degree, the possibility of increasing the output of the stoves by shortening the blast periods.

The answer to the first objection is that in stoves operating at least at normal pressure the losses by

* Throughout this paper 'tons' refers to metric tons.

* D. Petit: *JISI*, 1948, **160**, 131–138.

decompression are relatively small, and to the second, the same experts say that, in Russia, some stoves operate on 20 min blast periods. Blast periods of ½ h duration will be assumed, although it is admitted that they may be extended to 45 min or even 1 h.

Number of stoves in operation

Two-, three-, or four-stove installations exist, and today there is interest in running four stoves with two on blast at the same time. The outcome of these ideas will be interesting; meanwhile the method which is becoming standard in Europe consists of one stove on blast for ½ h, and two stoves on gas each for 1 h. With sufficiently clean gas and normal operating conditions, modern stoves, even at high temperatures, are not susceptible to frequent shutdowns for repairs; but these must nevertheless be allowed for, so that the blast-furnace can still operate on two stoves, though this means accepting a reduction in output.

Dimensions and design of stoves

Detailed calculations indicate the following optimum dimensions for stoves: height 126 ft (about 38 m) which can be reduced to 123 or 116 ft (about 37·36 or 35 m); and internal dia. 28 ft (about 8·5 m). Because of the increased temperature at the top of the stove, a rational design involves tapering the shell in order to increase the thermal insulation where necessary.

Generally stoves built in France are divided into three almost equal zones, the respective diameters of which are: lower third 27·9 ft (8·5 m), middle third 28·1 ft (8·62 m), upper third 28·6 ft (8·74 m). The internal dia. of the lining is throughout 25·2 ft (7·68 m); the thickness of this refractory lining is 14in (350 mm). It is backed by insulating bricks 2·4in (60 mm) thick for the lower third, 4·7in (120 mm) for the middle third, and 7·1in (180 mm) for the upper third. The thicknesses of insulation can, of course, be modified if desired, as can the thickness of refractory brick. While some stoves, e.g. in Belgium, have thin or very thin walls, this is not favoured by other engineers.

The dimensions of the combustion chamber depend on the gas rate and the temperature to be attained. In line with present-day techniques a quasi-elliptical combustion chamber is used but this is always constructed so as to be independent of the lining. Usually it has a cross-section of 54 ft² (5·0 m²), but sometimes of 60 ft² (5·6 m²).

Method of heating

Consideration is given to (*a*) the best performance to be obtained with gases of different calorific value each for different stack gas temperatures; (*b*) enrichment of blast-furnace gas by coke-oven or natural gas; (*c*) preheating combustion air or blast-furnace gas, or both; (*d*) enrichment of blast-furnace gas by oil or enrichment of combustion air by oxygen (these raise other technical or economic problems, however, which are not fully discussed).

STOVE CALCULATIONS: HEATING

Typical checkers: design and characteristics

Clearly the checkers are of major importance. Taking once more the typical dimensions of a modern stove (*see* Fig.1) the checkers will have: a cross-sectional area of 380 ft² (35 m²); a height of 102 ft (31 m); and a volume equivalent to 40 570 ft³ (1 147 m³).

TABLE I Comparison of dimensions on various European stoves

	*A*1	*A*2	*A*3	*B*
Spacing between holes, in (mm)	3·3 (85)	2·9 (75)	2·6 (66)	3·5 upper part (90) 2·4 lower part (60)
Total wt of checkers, tons	1 472	1 472	1 498	1 468
Surface area, ft² (m²)	370 900 (34 410)	439 600 (40 791)	503 100 (46 690)	464 800 (43 110)
Total surface area, ft² (m²) including dome and lining (approx.)	390 000 (36 000)	450 000 (42 000)	520 000 (48 000)	474 000 (44 500)

It is obvious that high temperatures demand better checkers. Earlier types with circular or square holes with a uniform cross-section from top to bottom could be considered for a blast of 600°C, but they do not meet current requirements. It is clear that the heat-exchange conditions of 1 200–1 400°C in the top zone differ considerably from the 150–200°C at the bottom. This implies that the checkers should vary from top to bottom. It is noteworthy that the high-temperature upper checkers have increased heat capacity because of their high specific gravity of 2·2 or more.

The characteristics of European types of high-temperature checker are given, and it will be noted that there is nowadays an increase in effective weight and effective surface area. It is this idea of effective surface area which has led to the 'variable turbulence stove' in which the turbulence increases towards the bottom of the stove. This is necessary and logical; the surfaces are fully used because of alternating protuberances.

The variable turbulence stove (*see ref.* p.34) is taken as the basis for study. The checkers have continuous holes from top to bottom which reduce obstruction, especially when the stove is under repair.

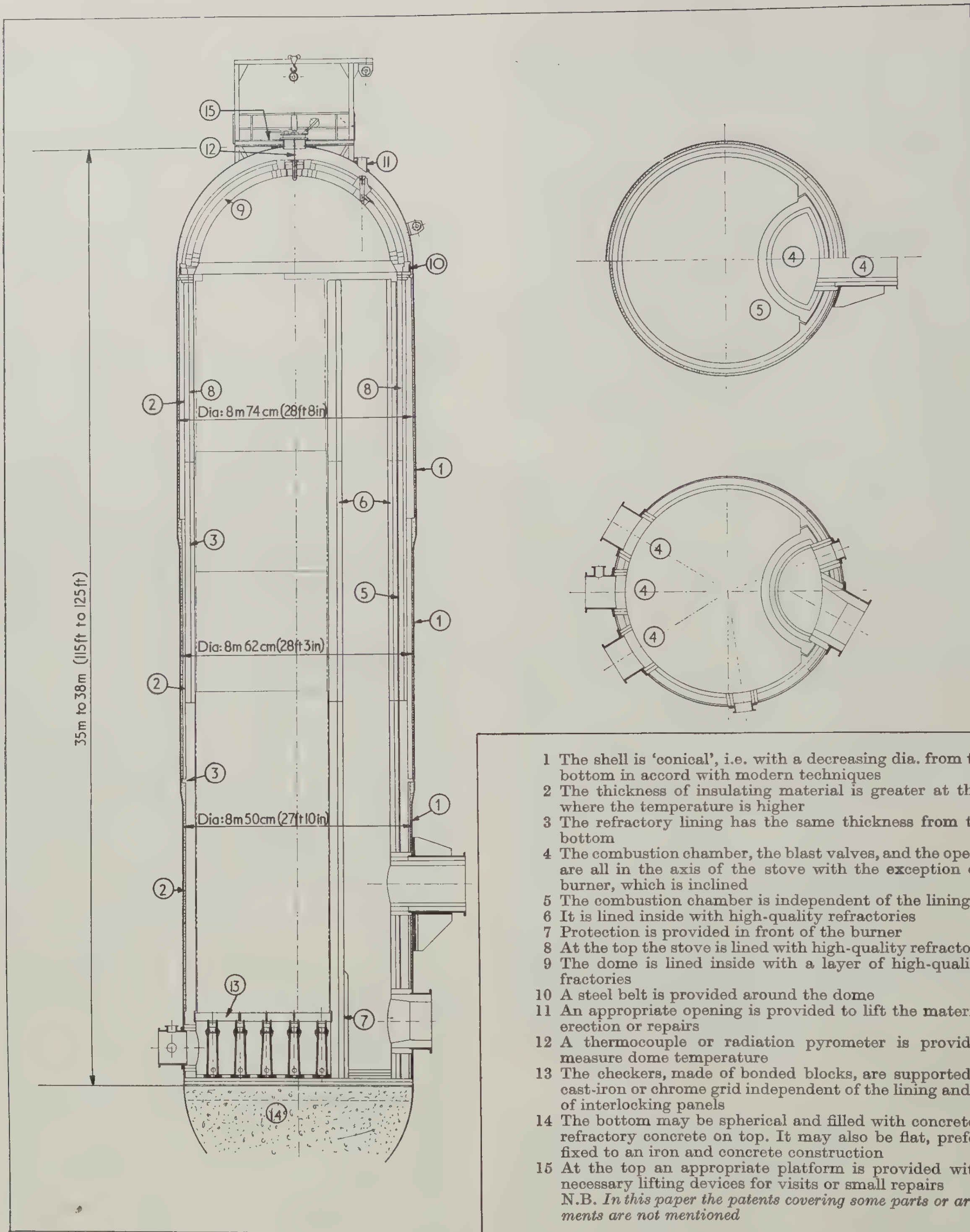
For comparison the details of checkers often used in Germany are given (referred to as stove *B*). These consist of four thick-walled holes in the upper part above nine smaller holes in the lower part.

Checkers may have 5 or 13 square holes in each block. With the typical square holes in European stoves considerable care should be paid to the inter-hole distance. This distance has been reduced progressively, and with a careful choice of wall thickness has led to the increased weight and surface area.

To begin with the variable turbulence stove had an inter-hole distance of 3·8in (96 mm). This has been reduced to 3·3in (85 mm), 2·9in (75 mm), and nowadays sometimes to 2·6in (66 mm) as is shown in Table I.

In comparison, an American checker with round holes would have a weight of 1 435 tons and a surface area of 276 500 ft² (25 640 m²).

The 3·3in (85 mm) inter-hole distance has minimum holes of 2in (50 mm) square and gives satisfactory performance for normal conditions, especially if there is a danger that the gas or air may carry some dust. The 3·0in (75 mm) distance is frequently used in modern installations in France. It has 1·6in (40 mm) holes and is used with highly efficient gas-cleaning



1 The shell is 'conical', i.e. with a decreasing dia. from top to bottom in accord with modern techniques
2 The thickness of insulating material is greater at the top where the temperature is higher
3 The refractory lining has the same thickness from top to bottom
4 The combustion chamber, the blast valves, and the openings, are all in the axis of the stove with the exception of the burner, which is inclined
5 The combustion chamber is independent of the lining
6 It is lined inside with high-quality refractories
7 Protection is provided in front of the burner
8 At the top the stove is lined with high-quality refractories
9 The dome is lined inside with a layer of high-quality refractories
10 A steel belt is provided around the dome
11 An appropriate opening is provided to lift the material for erection or repairs
12 A thermocouple or radiation pyrometer is provided to measure dome temperature
13 The checkers, made of bonded blocks, are supported by a cast-iron or chrome grid independent of the lining and made of interlocking panels
14 The bottom may be spherical and filled with concrete with refractory concrete on top. It may also be flat, preferably fixed to an iron and concrete construction
15 At the top an appropriate platform is provided with the necessary lifting devices for visits or small repairs

N.B. *In this paper the patents covering some parts or arrangements are not mentioned*

1 *Modern high-temperature stove corresponding to a set of three stoves and to a blast-furnace burning 1 200 tons of coke a day*

plant. The 2·6in (66 mm) distance, although technically the best, must be used with caution and only with very clean air and gas.

Stove *B* has satisfactory surface area but for most of its height it has vertical corrugations which are less favourable for heat exchange.

In all these checkers the wall thickness is about 0·8in (20 mm) for the lower parts, to reduce unnecessary weight or expense.

Checker calculations

For the mathematician, the problem with stove calculations is the selection of method.

Before the war especially, massive studies were published by several French and German specialists. These very complex papers were of only limited value because more or less arbitrary coefficients were adopted.

When the variable-turbulence stove was created in

1940, the design was based for better or worse on these investigations, but in view of the difficulty of adapting the theories, a simple graphical method was developed from temperature measurements in a checker at a works in the north of France (*see ref.* p.34). This method gave very satisfactory results for the operating conditions of stoves at the time and it also had the advantage of making it possible to calculate the thermal capacity of stoves.

In the last 5 or 10 years thermal specialists have made considerable progress. Coefficients, arguable 20 or 30 years ago, have been fully checked, and it is now possible to carry out stoves calculations which are sufficiently accurate without being too complicated. The best method is undoubtedly Professor Schack's; it is used in Europe by the main stove builders. Applications of this method will be found in the following section and in the appendix.

Heating with gas of 90 Btu/ft³ (800 cal/m³)

Phenomena dependent on the gas calorific value are considered below.

Flame temperature This is readily calculated as a theoretical temperature, and for the gas in question it has a value of about 1270°C. There are certain limitations to the usefulness of this theoretical value.

Effective temperature By this is meant the temperature which would be shown by a thermocouple protruding 4–6in (10–15 cm) from the centre of the dome. In this case it would be 1200°C.

Temperature of refractories The maximum temperature in a stove functioning normally is about 40°C below the effective dome temperature.

Maximum blast temperature at stove outlet Usually it is 120°C below maximum refractory temperature, i.e. 1040°C.

Minimum blast temperature at stove outlet This depends on the time on blast and for the stove in question would be:

880°C after 1 h, i.e. drop of 160°C
920°C after ¾ h, i.e. drop of 120°C
960°C after ½ h, i.e. drop of 80°C

Temperature regulated at the bustle main Depending on how the installation has been constructed, this is generally 70–75°C below the minimum temperature, i.e.

800–810°C with change every 1 h
840–850°C with change every ¾ h
880–890°C with change every ½ h

The advantages of shorter changeovers, immediately apparent from these figures, are: for a given calorific value of the gas, the temperature in the bustle main is higher; and for a given temperature in the bustle main, the temperature of the refractories can be lowered about 80°C compared with that corresponding to hourly changes.

All this is based on a fall in temperature of 160°C/h which is normal for large modern stoves operating at 97300 ft³/min (165000 m³/h).

Raising the stack temperature The normal operation considered gives a stack waste temperature of 100–150°C and an overall thermal efficiency of 87–90%. However, by raising the stack temperature it is possible to raise the temperature of refractories to 1200°C or higher to give a temperature at the bustle main of about 940°C when using ½ h on blast. This procedure reduces the thermal efficiency of the stoves and is limited in its effectiveness.

Discussion It must be admitted that apart from that for the flame temperature all figures are approximate. As a result of experience and trials they can be accepted as within 20° or 30°C. For example, repeated measurements with a radiation pyrometer have shown 150–200°C difference between the top checkers and the blast temperature. For a modern stove 170°C is realistic.

Cold-blast temperature 40°C has been assumed for normal operation. It must be remembered that if the cold blast is, say 120°C, then operation as discussed in 'Raising the stack temperature' above would lead to overheating of the grids and columns.

Heating with enriched gas

General While the above figures show that almost 1000°C can be obtained with 90 Btu/ft³ (800 cal/m³) of gas, rich ores and prepared burdens can produce gas of only 78 Btu/ft³ (700 cal/m³) and used straight this cannot produce the 1050°C required today.

The simplest method is to enrich with coke-oven gas (or S-free natural gas) whereby blast temperatures of 1200° or even 1300°C may be obtained.

Calculation to obtain 1050°C blast temperature A detailed calculation is given in the Appendix; the main conclusions are:

theoretical combustion temperature assuming an addition of 12% of coke-oven of gas 1445°C
effective combustion temperature about 1375°C
approximate max. temperature of refractories about 1320°C
temperature of blast at start of cycle about 1200°C
temperature of blast at end of cycle about 1120°C
temperature in bustle main about 1050°C
mean temperature of waste gas about 160°C
fall in temperature for half-hourly changeover about 92°C
efficiency of a well-insulated stove about 88·2%

Discussion The curves calculated for the temperature distribution correspond to the maximum under normal conditions.

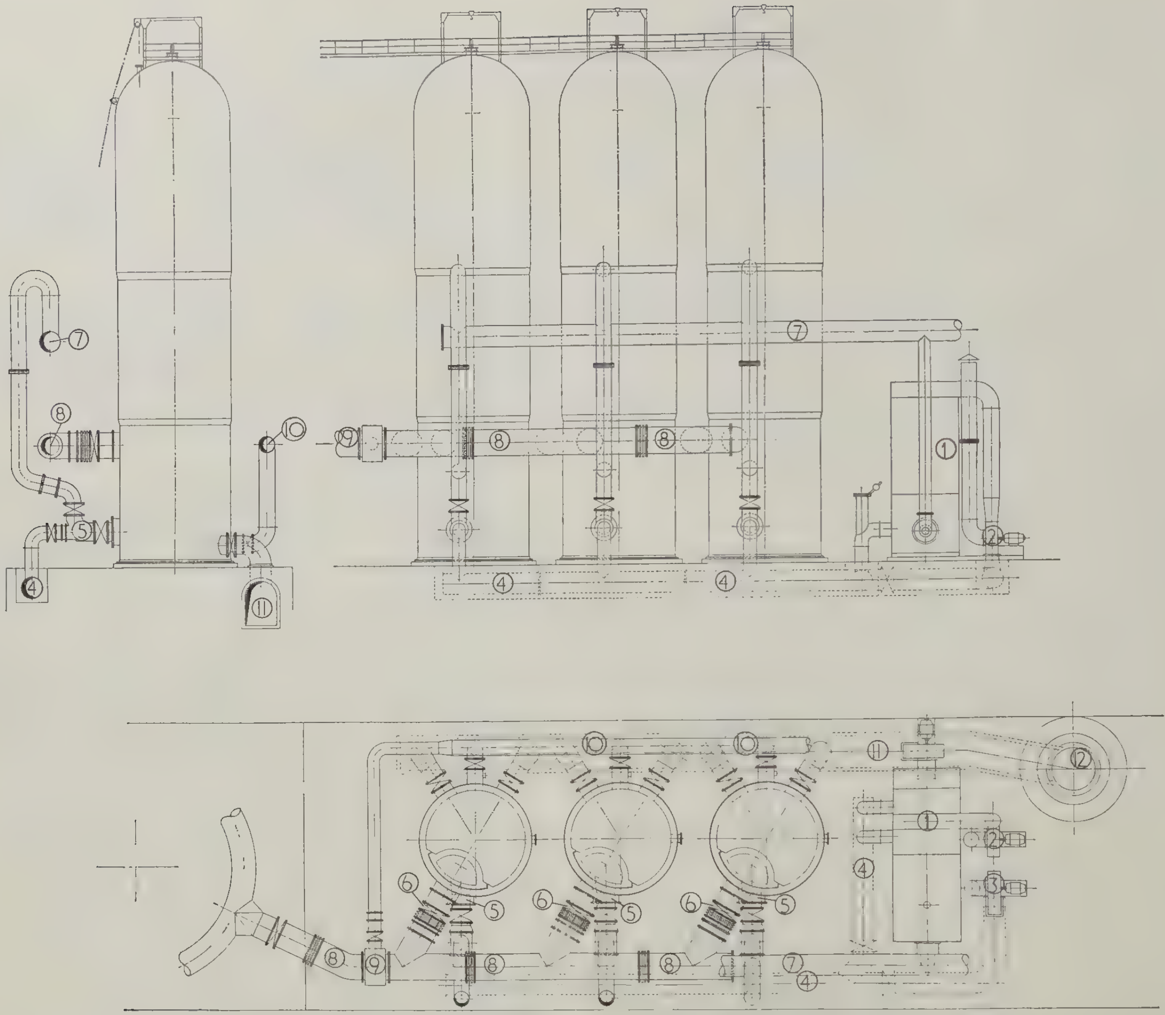
Conditions will vary during the life of a stove and higher temperature will bring down the checkers. When specifying the refractories, it is prudent to anticipate this and to allow an adequate margin of safety. Similarly, the best control and regulation must be installed to minimize accidental overheating.

Gas consumption, burner ratings, combustion chamber The theoretical total hourly consumption of mixed gas is:

Blast-furnace gas	1571000 ft³	44420 m³
Coke-oven gas	393000 ft³	11100 m³
Total	1964000 ft³	55520 m³

but in order to allow for changeovers and lost time the burners must be rated at 34200–35400 ft³/min (58–60000 m³/h) total. It is usual to rate burners at 70–80% of the total flow so that the stove duty is not drastically reduced should a stove be off. This means a burner rating of 24000–29000 ft³/min (40000–50000 m³/h) and the combustion chamber must be adequate for this flow.

In Europe experts agree that a 54 ft² (5·0 m²) combustion chamber is adequate whereas in the UK and USA a larger combustion chamber is preferred. The



1 Air preheater to 400–500°C
2 Fan for combustion air
3 Reserve fan in case of defect on the preheater
4 Preheated-air underground pipe delivering air to
5 Burner
(Another layout can be recommended, in which the burners are built first with individual fan, and when the preheater is built the hot air is delivered by pipes with valves on each burner, the individual fans then being used only in case of a defect on the preheater)
6 Hot-blast valves 'inclined' but in the axis of the stove and combustion chamber
7 Gas main pipe
8 Blast main pipe
9 Mixing of cold-blast main
10 Underground waste-gas main
11 Steel chimney which can be independent for each stove

N.B. *The use of preheated combustion air or preheated air and gas in stoves is patented*

2 *Set of three stoves with combustion air preheater*

alternative design showing 60 ft^2 (5·6 m^2) is provided for this preference.

Preheating the combustion air

General As an alternative to gas enrichment it is possible to obtain high blast temperature with lean gas by preheating the combustion air.

Operating characteristics of stoves with combustion air at 400–500°C First it should be stated that this temperature of 400°C has been chosen because with a gas of 90 Btu/ft^3 the bustle main, and also relatively inexpensive tubular preheaters, can be used.

The main characteristics of a three-stove installation supplied with preheated combustion air would be as follows:

theoretical combustion temperature 1425°C
effective combustion temperature about 1355°C
temperature of the hottest bricks about 1310°C
temperature of the blast at the start of the cycle about 1200°C
temperature of the blast at the end of the cycle about 1120°C
temperature controlled at the bustle main about 1050°C
the average efficiency, including that of the preheater about 85%
gas consumption in the stoves about 2800000 ft^3/h (80000 m^3)
gas consumption in the preheater about 530000 ft^3/h (15000 m^3)
total gas consumption about 3360000 ft^3/h (95000 m^3)

Preheater considerations There is no difficulty in building an air preheater for temperatures of 400°C. Several experts in the UK, France, and Germany, can provide easy and safe solutions to this problem. The cost of an apparatus of this type is relatively low, and it is undoubtedly a practical and simple solution.

Even when coke-oven gas is available it is worthwhile for a plant to consider whether, on balance, this scheme is not preferable.

Figure 2 shows the general arrangement of an installation of this type. The preheated combustion

air is fed to the burners by an underground main insulated by means of a simple Kieselguhr filling in the conduit. A stand-by fan has been provided.

Simultaneous preheating of gas and air

Should higher temperature be required, e.g. 1 200°C, then this is possible by heating both the gas and combustion air to 400°C. The operating characteristics should be as follows:

- theoretical combustion temperature 1 580°C
- effective combustion temperature about 1 500°C
- temperature of hottest bricks about 1 430°C
- blast temperature at start of blowing cycle about 1 340°C
- blast temperature at end of blowing cycle about 1 240°C
- temperature in the bustle main about 1 170°C
- average efficiency, including that of the preheater about 86%
- quantity of gas burnt in the stove 2 720 000 ft^3 (77 000 m^3)
- quantity of gas burnt in the preheater 1 170 000 ft^3 (33 000 m^3)
- total gas consumption 3 900 000 ft^3 (110 000 m^3)

No particular problems are envisaged because industry has much experience of preheaters at these temperatures.

CONSTRUCTION OF HIGH-TEMPERATURE STOVES

General

The construction of high-temperature stoves is complicated for many reasons, including generally the effect of operating at a pressure of 2 or 3 atmospheres, and the problem of the quality of refractories.

Checkers

Construction in columns Many stoves, particularly in America and the UK, use this construction. The checker blocks are built one above the other to form individual columns; sometimes the horizontal joints are broken and sometimes not. In practice these vertical columns can only be held upright by resting against the lining. This leads to wear and in Europe has caused real catastrophes. The use of vertical corrugations or polygonal linings has not completely solved this problem. This construction is not recommended for high temperature.

Bonded structure The checkers are designed in bonded blocks. A free space is left between the checkers and the lining, the bonded structure is therefore independent of the lining and the combustion chamber, so that no rubbing occurs.

In practice more clearance is used at the top of the stove because temperatures and horizontal expansion are greater. It is also wise to allow a slightly larger clearance between checkers and combustion chamber because of its tendency to lean towards the checkers.

Although modern refractories vary little in dimension, delivered checkers may be classified for height and selected to produce a perfect bonded structure. This solution is so obviously correct that it can be assumed as the only method which can be used in modern stoves.

Horizontal gas flow While German work has shown uneven distribution of air across checkers in the cold state, many tests on hot stoves have shown essentially even horizontal distribution at all levels. If the hot gases are maldistributed at the dome then any overheating causes immediate increase of the 'chimney' effect locally; this decreases the flow and forces the gases to the colder parts. In this way automatic self-compensation is obtained.

Analogous reasoning would show that this equalization also applies when on blast.

Some checkers have partial intercommunication between holes to minimize the effects of possible obstruction. While this view is feasible the author prefers, from experience, to use well-constructed continuous holes; these can readily be cleaned if necessary by a jet of compressed air, but the main advantage as explained before is the even distribution of gases.

Lower blocks The supporting grid, usually of cast iron, should be planed flat and designed so that the lower blocks placed upon it do not straddle two panels of grid.

The lower blocks are sometimes of different thickness and this is reasonable, but the use of a double cast-iron grid is thought to be expensive and unnecessary.

Steel shell

Conical shell To satisfy the thermal insulation requirements the only rational solution is to use a conical or stepped shell which has the largest diameter at the top.

Dome Domes may be hemispherical or semi-flat. While both can be satisfactory, the hemispherical form leads to a better construction from the point of view of refractories.

Flat bottom Flat-bottom plates are securely anchored to the concrete slab.

They cannot, however, tolerate thermal forces, and particularly with cylindrical stoves, can suffer mechanical stresses due to rubbing between lining caused by differential expansion. These forces can lead to deformation of the bottom plate, leaks, and even cracks in the shell.

One successful solution has been achieved in eastern France. The bottom plate is bolted on an iron–concrete construction. Inside the stove the bottom plate is protected by 3–6 ft of normal concrete and 2–3in of refractory concrete. This avoids thermal stresses on the plate and gives a technical solution which is also economical.

(i) Spherical bottom Many stoves built or designed recently in France have a spherical bottom. The stove is supported by a 'crown' to leave a space between the steel hemisphere and the concrete raft. The inside of the hemisphere is filled with concrete and protected by refractory concrete.

(ii) GHH solution The Guthoffnungshütte AG have patented a design in which the shell itself is anchored to the concrete foundations.

Lining

General Solutions which were satisfactory on small stoves with domes at 1 200°C are no longer satisfactory on large stoves with domes at 1 400°C.

With a lining periphery of 100 ft or so at today's temperatures there is considerable thermal expansion. This, and the increased weight and expense, precludes the use of corrugated or polygonal linings. Only circular linings can be satisfactory and these should be built with a double layer of refractory having well-bonded joints around the whole periphery.

Thin linings High-pressure salesmanship by certain

refractory and insulation brickmakers has led to installations having thin linings. Although first-class materials are used, it can be argued that this practice carries long term risks which are not worthwhile.

If existing shells are too small, then risks may be taken to increase the volume of checkers and this action may be justified, but not for new installations.

Variable thickness linings Some years ago the Americans used a constant thickness of insulation backing the refractory lining. In the lower levels this insulation serves no useful purpose.

In Europe, with cylindrical shells, refractory linings of variable thickness are often used. These are thicker at the bottom, sometimes as much as 18in, and about 12–14in at the top. This is quite wrong because the thickness is least where it is most needed and vice versa. It also gives a poor utilization of the shell and is wasteful in materials.

With such a thin lining in the upper parts of the present large stoves there are more dangerous hot spots because large stoves cannot be perfectly vertical and perfectly round.

If the brickwork is to be built truly vertical and cylindrical, then imperfections of the shell will reduce the lining thickness in places, and for an already thin lining this will lead to hot spots.

Conical shells Figure 1 shows the recommended construction, although dimensions for the refractory lining or the insulation may be modified to accommodate different quality materials. This design satisfies all requirements of insulation where it is needed: tolerance to shell imperfections, reduction of friction forces, and stress to the shell due to thermal expansion, etc.

Combustion chamber

General In 30 years' experience the author has found that the combustion chamber is the critical point of a stove; eight times out of ten it is the combustion chamber which demands attention if there are refractory failures. They are asymmetrically heated and opposite walls have vastly different heat losses, owing to the one being backed by checkers and the other by the lining.

Every precaution is always taken but frequently the combustion chamber does lean.

Ideally combustion chambers should be circular but quasi-elliptical ones which take up less room and require less refractory are normally used. It is also claimed by some operators that they give better air and gas distribution. Although recent installations of oval combustion chambers have stood up well, it is not proven that this is the best solution for high temperatures.

For most of its height the temperature of the inside of the combustion chamber is greater than outside. For this reason most modern stoves have an inside-independent grade material which performs well in practice.

The distance between the burner and the hot-blast outlet must be carefully chosen. Generally it is 27–30 ft, and combustion of the gas should be complete within this distance, so that should the hot-blast valve leak there will be no danger from abnormally high temperatures.

Independence of lining and combustion chamber Experience has been that stoves with an independent combustion chamber have shown a differential movement at the top of 4–6in between the combustion chamber and the lining. This can clearly be seen from glazing on bricks when examining a stove which has cooled down. In Europe combustion chambers are, as a result, invariably built independent of the lining, having a clearance of about 3–8in; the combustion chamber is designed as a well-bonded structure. This desirable practice is not often followed in the USA.

General arrangement of combustion chamber Most European stoves have the hot-blast port above the burner entry, whereas in the USA the burner is frequently above the hot-blast exit. The European system has advantages when used with flat valves whereas the US is designed for mushroom valve. The upper burner introduces difficulties in protecting the lining opposite the burner entry, whereas 6–9 ft of protective brickwork is readily installed with the burner in the lower position. Also the upper burner has the disadvantage that the hot blast passes the burner entry: this calls for special valves, preferably with water cooling at this point.

It has, however, certain advantages in access to the valves and combustion chamber during stove construction. Also with the usual cold-blast addition the hot-blast valve operates at a lower temperature, although this is becoming less and less common because in these days of high blast temperature less cold air is used.

Dome

General Domes run at high temperatures can weep when excessive dust in the gas fuses with the refractories. However, in 30 years' experience, the author has found no problems with well-constructed domes operating with clean gas and normal temperatures. Provided the inner lining of the dome is well constructed from best quality materials, there should be no problem even at high dome temperatures.

As a rule domes must be insulated. A double construction of refractory and insulating brick is often used, sometimes backed with a layer of refractory mastic. With really high temperatures it may even pay to have less insulation, so as to reduce brick temperature and therefore excessive brick conditions.

There is usually a 12–16in space between the dome and the shell. During reversals this space is refilled with hot gases which can heat the outer steel shell. Certain German constructors line the steel shell with refractories because of this. French constructors, however, are reluctant to use this construction in case it should lead to overheating the refractories.

Large pressure changes on reversal on large domes could cause damage by lifting the dome refractories. On some installations in France there is a valve-controlled main installed between the stove and the space between the dome shell and refractories.

Dome banding A welded band 9×1in is installed to withstand the lateral brick stresses. This is considered to be essential.

Opening in the top Lateral openings in the dome should not be provided because they weaken the dome structure. A single opening which is readily sealed by an appropriate device is usually provided in the top centre.

Grids

Supported by or independent of the brickwork Modern stoves have a 48in cold-air inlet and two 55in waste-gas outlets which weaken the lining from the point of view of supporting the grid and checkers. It is strongly recommended that the grid should be quite independent of the lining and modern stoves have this construction.

Construction of the grid Independent grids are supported by cast columns. Mostly the grids are cast iron, although these are expensive because of patterns and machining.

It is recommended that the grid elements, according to one of the author's patents, should be fitted in to one another to make a monoblock for reliable and easy erection. Even so it is advantageous to shop-erect and to number these components.

One German company supports four grid elements by a column at the intersection, the grid being similarly supported by a cast-iron ring supported by the walls.

American designers sometimes use one column per grid element thereby ensuring an independent grid.

Cast-iron or chrome grids High quality hematite grids used to be normal, but today many operators prefer low-chromium alloys to increase the safe operating temperature by about 200°C. The extra expense is relatively small and is worthwhile for the extra margin of safety.

With cold blast of 150°C and waste gases at 200°C or more, reliable devices are worth installing to prevent overheating.

Burners

Classification: open and closed Open burners have a so-called Cowper valve which completely isolates the burner when the stove is on blast, so that the burner is never under blast pressure. For high-temperature operation this Cowper valve can be water-cooled or made of special steel. In any case its operation is always safe: any leaks are immediately visible and are only an escape to atmosphere.

Closed burners, however, necessitate an air valve which must withstand blast pressures, and a double, or at least double-seated, gas valve, to prevent air passing back into the gas main. Closed burners are more complicated because they have to be brick lined for protection from heat. Should one of the valves leak, the whole burner can readily be heated to the blast temperature of perhaps 1000°C. This risk is reduced by using two water-cooled valves, but this method is complicated and costly.

Earlier open burners normally had the air blown in from the back through a type of helix. One problem was that explosions in the combustion chamber could wreck the helix and the motor.

Nowadays most stoves have individual centrifugal fans placed above or below the burner, although some installations have a single fan piped to supply two or three stoves.

Open burners with individual fans are strongly recommended, particularly when stoves operate at high temperature and high pressures.

Burner control mechanism Most modern installations rightly have regulators to control the proportion of air and gas for combustion. Usually they operate to give an excess air supply of 5–20%. Askania-type controls are frequently used and are excellent, provided sufficient lengths of straight runs of pipe are used for accurate flow measurement. This encourages raising the air inlet to a position where the air is much cleaner. In some cases air can carry more dust into the stove than the gas does.

When a mixture of blast-furnace and coke-oven gas is used, a control instrument is normally used to determine the proportions of each gas and therefore the calorific value.

A further problem arises when changes in flame temperature and in heat input are required. If the air or the gas is to be changed, the most common method is to change the gas by a butterfly valve. Some operators, on the other hand, change the air rate, partly because air pressures are more steady than gas pressures and therefore give closer control. In both cases the changes can be by manual or automatic operation.

The gas butterfly valve controlling the flow for the burner can serve as a safety device, but generally two butterflies are places in series. These are: the regulating butterfly, and the safety butterfly which automatically closes when necessary, e.g. when the dome temperature exceeds a certain limit, when the air supply fails, owing to a fan breakdown, or for some other reason (generally, also, heating will automatically stop if there is a furnace breakdown).

While relying on the safety devices to reduce the gas rate it is desirable that a sound alarm should also operate to attract attention in cases of abnormal operation.

Waste-gas oxygen analyses are sometimes requested. These are complicated and expensive and do not appear to be justified; the occasional analysis of waste gas by Orsat is usually adequate.

Valves

General The layout of the old American installation is well known. It is fitted with mushroom blast valves and complicates the lateral main arrangements.

In Europe mechanized flat valves operating vertically are normally used. These are controlled by compressed air cylinders, or electrically powered.

The author prefers compressed air because the valves are more flexible, more positive and a reserve of air can be available even with a power failure.

Compression and decompression equipment are of two types: in high-pressure equipment it is better to have special 1 ft dia. valves automatically controlled; for economy reasons there is sometimes a small slide valve designed into the cold-blast valves and one of the waste-gas valves.

Hot-blast valves For high blast temperatures hot-blast valves must be water cooled. Even so the lower part of the valve should always be kept warmed. For troublesome water a simple circulating system may be used which cools the water in a radiator, very similar to a car's cooling system.

Automation For 30 years at least, pneumatically or electrically controlled valves have been used. These are operated by simple push-button or lever. Coloured lights show on a panel the position of each valve. Surprisingly this practice is less established in the USA where many valves are often still manually operated.

Mechanized valve changing becomes imperative for high-temperature stoves with short cycles of $\frac{1}{2}$ or $\frac{3}{4}$ h

TABLE II Analysis of fireclay bricks of French manufacture

Alumina True	Apparent ($Al_2O_3+TiO_2$)	Fe_2O_3, %	CaO+MgO, %	Na_2O+K_2O, %	Total fluxes	Refractoriness	Cone no.	Shrinkage Under load (hot)*	After 1 h at 1500°C	After 1 h at 1600°C
44–47	45–48	1	0·5	0·5	2	1760–70	34–35	1470–1530	0·2–0·5	0·3–1
42–44	43–45	1·7	0·5	0·5	3	1760	34–35	1460–1520	0·2–0·5	0·3–1
40–42	41–43	1·7	0·5	0·5	3	1750	34	1435–1510	0·2–0·6	0·3–1
35–40	36–41	2	0·5	...	3	1730	33	1415–1450	0·5–0·8	...
32–35	33–36	2·5	0·5	0·5	3·5	1720	32–33	1410–1420	0·8	...

* 0·5% under 2 kg/cm²

on blast. In addition, at these periods it is worthwhile to automate completely the stove changing.

Changeover and control may be initiated by the dome temperature, waste-gas temperature, and cold-blast flow in the blast, but instrumentation at these important points is neither perfect nor thoroughly reliable.

The author has recently patented a simple system to overcome these objections. It is not full automation but allows the operator to make infrequent adjustments to keep the whole system in perfect balance. The system is to arrange for automatic changeover under clockwork control. The time on blast may be, for example, ½ h, but would be adjustable from 20 to 45 min.

If the burner rating is set too high or low the blast-temperature recorder operates a sound alarm whenever the blast temperature deviates by 25°C, whereupon the operator resets the gas burning rate on all stoves. Automatic resetting of gas rates to obtain the required blast temperature may also be incorporated.

Measuring control and safety mechanisms

General To obtain high temperature demands good instrumentation and control in order to obtain the highest duty, in safety, from an installation.

Measurement of dome temperatures Thermocouples are normally installed in the dome to measure the temperature of the hot gases. Unfortunately, in spite of every precaution, the results obtained can vary markedly.

In France, there is a trend now to use radiation pyrometers sighted on a blind silicon–carbide tube at the top of the dome. Development work is still in hand.

Regulation of cold blast The best point for cold-blast entry is difficult to choose. Sometimes it is added before the hot-blast valve in order to have the minimum temperature at the valve. In other cases it is added between the hot valve and the blast-furnace. Much depends on local circumstances and design of valves and layout.

General arrangement of stoves

Waste-gas removal In Europe an underground main is generally used and this leads to a steel chimney. Sometimes the underground main is replaced by one above ground but in this case it has to be well insulated. Another way is to install a chimney alongside each stove.

The method adopted will depend on practice and siting convenience. When stoves are decompressed the air in them is generally vented into the waste-gas main. This can cause difficulties if the main dimensions are not correctly chosen. Alternatively the air may be vented to atmosphere but then an effective silencer is most desirable.

Platforms and access requirements depend on the layout, but on modern stoves a platform at the level of the top of the dome is essential. This should be large enough to accommodate certain quantities of refractories for repairs.

Refractories

The author managed a group of four plants making refractories from 1930 to 1940; in 1938 he presented to the British Ceramic Society diagrams showing calculations for refractories: these can still be used as a basis for design. For stoves, refractories may be divided into three categories:

Ordinary products These are normal fireclay products with a maximum of 40–42% alumina. Clearly more than half, and perhaps two-thirds, of the refractories in a stove do not operate under severe conditions of temperature or load. In practice 30–32% to 40–42% Al_2O_3 refractories are used for these duties and are perfectly adequate.

Second category These are made of first-class fireclays sometimes with an addition of material of higher alumina content. Their analysis depends on the country of origin; and typical analyses for such bricks made in France are shown in Table II. These refractories are of excellent quality and may be used in stoves operating at 1000–1050°C.

TABLE III Data for English special products with higher alumina contents

	Sillmax 54	Sillmax 63–100
Al_2O_3, %	52–54	61–64
Fe_2O_3, %	1·5–2·5	0·3–0·6
TiO_2, %	0·3–0·5	1·0–1·8
CaO–MgO, %	0·3–0·8	Nil–trace
Alkalis, %	0·5–0·9	0·4–0·6
SiO_2	Balance	Balance
Physical properties		
True porosity, %	18–20	17–20
Apparent porosity, %	17–19	16–19
Bulk density	2·36–2·42	2·55–2·65
Refractoriness, °C	1790	+1810
Permanent linear change, %		
2 h at 1400°C	Nil	Nil
2 h at 1500°C	Nil–0·2	Nil–+0·2
2 h at 1600°C	+0·2	+0·5
Maintained refractoriness under load 2 h at 28 lb/in² (2 kg/cm²)		
Subsidence at 1500°C, %	2	...
Subsidence at 1650°C, %	...	2·5–3·5
Cold crushing strength, lb/in²	5000–6000	3500–5000
BCRA standard spalling test, cycles	+30	+30
Permeability, cgs units	0·02–0·04	0·02–0·05
Coefficient of reversible thermal expansion, 10–5	0·47	0·41
Thermal conductivity above 1000°C, Btu	12–13	12
Wt/ft³, lb	150	166
Wt/m³, kg	2403	2659

Third category: special products These have higher alumina contents because mixtures are used containing andalusite, silimanite, etc. Data for typical English products are given in Table III. These are suitable for the critical points in stoves operating over 1000°C blast heat.

Silica bricks Silica bricks have very good hot strength but have several disadvantages in stoves: they have relatively low density; they glaze when subjected to dust; their well known poor resistance to temperature changes has made operators avoid them.

In 1930 considerable quantities of high-silica, low-alumina (20–26%) bricks were made in France for use in stoves. They gave excellent results even at temperatures up to 1320°C but are not used today. Some years ago the Americans used a low-alumina brick (called the Valentine) for high-temperature stove duties. Most operators are today, however, turning to the high-alumina bricks for high temperatures.

Checkers refractories

Diagrams can be made to indicate the theoretical temperature distribution in the checkers. Practically, only the operator knows the temperature at the top and bottom levels, and little is generally known about the temperature at the critical level 30 ft below the top checkers. There the refractories are under load, as well as at elevated temperatures. Also it is possible to operate the stoves to obtain different temperature distributions: perhaps a straight line or an inverse curve. It is therefore prudent to specify better bricks than theory might indicate. This concerns particularly the top 30–50 ft of checkers. Many are investigating these problems and their results are awaited with interest.

Other refractories

Dome Although dome failures due to temperature are unusual, today's dome temperatures demand every precaution. The inner dome arch should be somewhat thicker and constructed from special high-temperature refractories.

Lining Linings have to support perhaps 80 tons of dome, and for this reason they should be adequately thick. The lining is generally made from refractories in the second category, but the inside bricks should be of special refractory in the upper part for very high temperatures.

Combustion chamber For 1000–1050° at the bustle main, refractories of the second category are considered adequate in France. For higher temperatures special refractories must be used in the upper part of the combustion chamber, at least for the inside lining.

Insulation

Material with a Kieselguhr or similar base

Generally speaking there is considerable latitude in the quality which may be used in stoves. This, of course, presumes it is used only to back a well-bonded refractory structure. In France there has been a tendency to abandon Kieselguhr type products because of their friability. Certain US products are of high quality and have given excellent results.

Refractory insulators

In this group are refractory products which have been given an artificial porosity. They have a density of 0·6–1·0 and some have remarkable properties. In France these products are frequently used for backing the upper part of the lining or backing the dome.

Other insulating products

There are three main types of these materials:

Panels of asbestos which can be used behind the lining and the dome. It is advisable to use only first-quality materials.

Use of an air gap between the insulation and the shell and sometimes even between refractory and insulation. Sometimes the air gap is filled with Kieselguhr powder or granules. Air gaps are not to be recommended in high-pressure stoves and powders have a tendency to settle in spite of all precautions.

Refractory mastics which contain asbestos in powdery form and are moist. They set lightly on drying and can accommodate differences of expansion. These are recommended between lining and shell, and sometimes behind the dome-insulating material. They have the great advantage of accommodating any errors of construction between lining and shell.

Generally speaking, the use of a conical shell simplifies the question of the choice of insulation material.

CONCLUSIONS

Modern stoves can operate on lean gas enriched with coke-oven gas to supply blast temperatures of 1050°C at the bustle main. This result may also be obtained with preheated combustion air or gas. In the near future stoves will be built to obtain 1200°C at the bustle main.

Sufficient data is given to ensure successful design and operation of modern high-temperature stoves. These conditions may be thought excessive for today's conditions, but it must be remembered that new installations are built to last 20–30 years. Foresight is essential if premature obsolescence is to be avoided.

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APPENDIXES

1 Type study for a high-temperature stove

General

Conical shell	Min. dia. 28 ft (8·5 m)
Total height	125 ft (38 m)
Oval combustion chamber	Cross-sectional area 54 ft² (5 m²)
Three-stove operation	Two on gas, one on blast (1 h on gas $+\frac{1}{2}$ h on air)

Heating

Blast-furnace gas	90 Btu/ft³ (800 cal/m³)
Temperature of blast-furnace gas	30°C
Relative humidity	100%
Coke-oven gas	500 Btu/ft³ (4500 cals/m³)

Air

Temperature	10°C
Relative humidity	75%
Barometric pressure	745 mmHg
Excess air	10%

Blowing

Air:	
Rate	97 000 ft³/min (165 000 m³/h)
equivalent to	1 200 tons coke/d
Pressure	35 lb/in² (2·5 kg/cm²)
Humidity	10 gr/ft² (25 g/m³)
Temperature at stove inlet	40°C
Fall in temperature between outlet of stove and bustle pipe	70°C
Temperature in the bustle pipe at the end of ½-h blast period	1 050°C

General study

The proposed stove has a conical shell, i.e. with three diameters:

lower part 8·50 m (27·9 ft) for 12·63 m (41·4 ft)
middle part 8·62 m (28·3 ft) for 9·50 m (31·2 ft)
upper part 8·74 m (28·7 ft) for 11·50 m (37·7 ft)

The dome is hemispherical.
The refractory dome has two arches; the inside one is 300 mm thick (12in)
The refractory lining has a uniform thickness of 350 mm throughout its height.
The insulation has various thicknesses according to the dia. of the shell:

lower part 60 mm (2·4in)
middle part 120 mm (4·8in)
upper part 180 mm (7·2in)

These thicknesses are increased by 30 mm (1·2in) alongside the combustion chamber.
The internal diameter of the brickwork is about 7·68 m (25·2 ft).
The quasi-elliptical combustion chamber, free of the lining in a vertical direction, is formed by two free-standing walls.
Its horizontal surface area is 5·0 m² (54 ft²) which corresponds to a circular combustion chamber of 2·50 m (8·2 ft) diameter.
The checkerwork proposed is of the variable turbulence type with three zones having a spacing of 75 mm (3in) between the holes.
Its horizontal cross-sectional area is 37·00 m² (400 ft²). The total height of the checkerwork is 31·00 m (102 ft).
The checkerwork is mounted on a cast iron grid independent of the brickwork.
The checker bricks are mounted tied and cross-jointed in horizontal layers giving great stability and providing for clearance between the checkerwork and the lining and combustion chamber; this clearance increases with the height in the stove.

Heat calculation

Combustion with a mixed gas

88% BF gas (800 cal)+12% coke-oven gas 4 500 cal)
Composition, %
CO_2 12, CO 24·4, H_2 7·5, CH_4 2·9, C_2H_4 0·4, N_2 52·5.
Calculated CV: 1 240 cal/m³; or with 12 cal for the sensible heat of the gas and the combustion air: 1 252 cal/m³.

Air necessary for combustion

$$O_2=\frac{0\cdot244+0\cdot075}{2}+2\times0\cdot029+3\times0\cdot004 \qquad =0\cdot230\ \text{m}^3$$

Amount of air including 10% excess air:

$$0\cdot230\times\frac{100}{21}\times1\cdot10 \qquad =1\cdot205\ \text{m}^3$$

Composition of waste gases

$$CO_2=0\cdot120+0\cdot244+0\cdot029+(2\times0\cdot004) \qquad =0\cdot401\ \text{m}^3$$
$$H_2O=0\cdot30+0\cdot075+(2\times0\cdot029)+(2\times0\cdot004) \qquad =0\cdot171\ \text{m}^3$$
$$N_2+O_2=0\cdot525+(1\cdot205-0\cdot230) \qquad =1\cdot500\ \text{m}^3$$
$$2\cdot072\ \text{m}^3$$

The sensible heat of the waste gases at 1 500°C is

$$N_2+O_2=1\cdot500\times519\cdot3 \qquad = 778$$
$$H_2O \quad =0\cdot171\times835\cdot6 \qquad = 143$$
$$CO_2 \quad =0\cdot401\times945\cdot6 \qquad = 379$$
$$1\,300\ \text{cal}$$

Theoretical temperature of combustion

$$1\,500\times\frac{1\,252}{1\,300}=1\,445°\text{C}$$

or an effective flame temperature of

$$1\,445\times0\cdot95=1\,373°\text{C}$$

Amount of heat required for the blast

To obtain a hot-blast temperature of 1050°C in the bustle pipe, a temperature of 1 120°C must be reached in the stove at the end of blowing.
To raise the temperature of 1 m³ of blast from 40° to 1 120°C (*see* Table, A 1) requires 368 cal, or

$$165\,000\times368=60\,720\,000\ \text{cal/h}$$

the mean outlet temperature being 1 160°,
1 m³ of blast carries 383 calories
The mean volume of blast passing through the stove is

$$\frac{60\,720\,000}{383}=158\,540\ \text{m}^3/\text{h approx.}$$

Amount of burner gas (at the stove)

Efficiency assumed: 88%

$$\frac{60\,720\,000}{1\,240\times0\cdot88}=55\,700\ \text{m}^3/\text{h approx.}$$

The theoretical quantity of gas to be burnt in the stove will be about

$$55\,700\times1\cdot205=67\,118\ \text{m}^3/\text{h}$$

1 m³ of gas at 1 240 cal produces 2·07 m³ of waste gas and the volume of waste gases passing in each stove is about

$$28\,000\times2\cdot07=57\,960\ \text{m}^3/\text{h}$$

Gas velocity through the checkers

The following velocities are at NTP:

Air *Waste gas*

Upper part

$$V_1=\frac{158\,540}{3\,600\times10\cdot36}=4\cdot25\ \text{m/s} \qquad V'_1=\frac{57\,960}{3\,600\times10\cdot36}=1\cdot56\ \text{m/s}$$

Middle part

$$V_2=\frac{158\,540}{3\,600\times14\cdot80}=2\cdot98\ \text{m/s} \qquad V'_2=\frac{57\,960}{3\,600\times14\cdot80}=1\cdot09\ \text{m/s}$$

Lower part

$$V_3=\frac{158\,540}{3\,600\times17\cdot76}=2\cdot48\ \text{m/s} \qquad V'_3=\frac{57\,960}{3\,600\times17\cdot76}=0\cdot91\ \text{m/s}$$

Convection coefficients (cal/m²/h/°C)

Air *Waste gas*

Upper part

$$\alpha_1=\frac{5\sqrt{4\cdot25}}{3\sqrt{0\cdot040}}=30\cdot1 \qquad \alpha'_1=\frac{5\sqrt{1\cdot56}}{3\sqrt{0\cdot040}}=18\cdot3$$

Middle part

$$\alpha_2=\frac{5\sqrt{2\cdot98}}{3\sqrt{0\cdot044}}=24\cdot4 \qquad \alpha'_2=\frac{5\sqrt{1\cdot09}}{3\sqrt{0\cdot044}}=11\cdot8$$

Lower part

$$\alpha_3=\frac{5\sqrt{2\cdot48}}{3\sqrt{0\cdot045}}=22\cdot1 \qquad \alpha'_3=\frac{5\sqrt{0\cdot91}}{3\sqrt{0\cdot045}}=10\cdot7$$

Radiation coefficients

For the waste gases, it is necessary to add the radiation coefficient:

TABLE A1 Conical-shell stove (inter-hole distance 85 mm)

	Size of hole, mm (in)	Wall thickness, mm (in)	Height, m (ft)	Porosity, %	Wt/m³, kg (ft³, lb)	Total wt, tons	Surface area/m³, m² (ft²)	Total surface area, m² (ft²)
Radiant head blocks without protuberances	50 (1·97)	35 (1·38)	9 (29·5)	34·2	d=2·20 1448 (65–66) d=2·05 1349 (61–62)	470	26·5 2·18	8·825 (95·100)
Middle turbulence zone blocks with two protuberances	55 (2·17)	30 (1·18)	9 (29·5)	37·8	d=2·05 1275 (57·8)	425	29·5 (2·42)	9·825 (108·000)
Filter blocks with six protuberances	60 (2·36)	25 (0·98)	13 (42·5)	41·5	d=2·05 1200 (544)	577	39 (3·2)	18·760 (202·200)
						Total wt 1472 tons	Total surface area 37·410m² 405·300 ft²	

TABLE A2 Conical-shell stove (inter-hole distance 75 mm)

	Size of hole, mm	Wall thickness, mm	Height, m	Volume, m³	Porosity, %	Weight, kg/m³	Total wt, tons	Surface area/m³, m²	Total heating surface, m²	Cross-section of holes, m²
Radiant head square holes	40	35	11·000	407	28	d=2·20 1584 d=2·05 1476	623	28·4	11·560	10·36
Middle turbulence zone blocks with two protuberances	50	25	10·000	370	40	d=2·05 1230	455	36	13·320	14·80
Filter blocks with four protuberances	55	20	10·000	370	48	d=2·05	394	43	15·910	17·76
							Total wt 1472 tons		Total surface area 40·790 m²	

TABLE A3 Conical-shell stove (inter-hole distance 66 mm)

	Size of hole, mm	Wall thickness, mm	Height, m	Volume, m³	Porosity, %	Wt/m³, kg	Total wt, tons	Surface area/m³, m²	Total heating surface, m²	Cross-section of holes, m²
Radiant head square holes	38	28	11·000	407	33	d=2·20 1474 d=2·05 1374	580	34·8	14·164	12·21
Middle turbulence zone blocks with two protuberances	42	24	10·000	370	35·4	d=2·05 1324	490	40·5	14·986	13·10
Filter blocks with four protuberances	46	20	10·000	370	43·6	d=2·05 1156	428	47·4	17·540	16·13
							Total wt 1498 tons		Total surface area 46·690 m²	

Upper part: $\rho_1 = 8{\cdot}3$ cal.m²/h
Middle part: $\rho_2 = 3{\cdot}3$ cal.m²/h
Lower part: $\rho_3 = 1{\cdot}2$ cal.m²/h

Mean coefficients for the whole of the checkers
Because of the way the zones have been divided up one-third of the heat exchange takes place in each zone

$$m\ (\text{air}) = \frac{30{\cdot}1 + 24{\cdot}4 + 22{\cdot}1}{3} = 25{\cdot}5\ \text{cal.m}^2/\text{h}/^\circ\text{C}$$

$$m\ (\text{waste gas}) = \frac{26{\cdot}6 + 15{\cdot}1 + 11{\cdot}9}{3} = 17{\cdot}9\ \text{cal.m}^2/\text{h}/^\circ\text{C}$$

Overall heat-exchange coefficient for period

$$K_p = \frac{0{\cdot}75}{\dfrac{1}{25{\cdot}5} + \dfrac{8{\cdot}1}{2 \times 17{\cdot}9}} = 11{\cdot}17\ \text{cal.m}^2/\text{h}/^\circ\text{C}$$

Mean duty on blast

$$\frac{60\,720\,000}{40\,790\times0{\cdot}95}=1\,567\ \text{cal.m}^2/\text{h}=9{\cdot}63\ \text{Btu/ft}^2/\text{min on blast}$$

Calculation of the mean waste-gas temperature

$$\frac{1\,567}{11{\cdot}17}=\frac{(1\,320-1\,160)-(\text{tf}-40)}{2{\cdot}303\log_{10}\dfrac{1\,320-1\,160}{\text{tf}-40}}=\text{tf}=162°\text{C}$$

Temperature drop/h

$$\Delta t=\frac{60\,720\,000}{1\,472\times250\times0{\cdot}86\,\dfrac{(1+205\,000\times0{\cdot}26)}{(25{\cdot}5\times40\,790)}}=185°\text{C}$$

External heat losses and waste-gas heat losses

The external surface area of a stove is 1 030 m^2.
The average heat loss from the shell is about 580 cal.m^2/h.
For three-stove operation, the total heat loss will be about:

$$1\,030\times3\times580=1\,792\,000\ \text{cal/h}.$$

The theoretical exit temperature of the waste gases is about 162°C.
The loss per m^3 of dry gas burnt is about 144 cal.

Gas consumption

$$\frac{60\,720\,000+1\,792\,200}{1\,240-114}=55\,520\ \text{m}^3/\text{h}$$

Rough efficiency of a stove

$$\frac{60\,720\,000}{55\,520\times1\,240}=88{\cdot}2\%$$

Gas consumption by stove

The overall consumption is 55 520 m^3/h.
Taking into account stove cycles, the flow/h during heating will be about

$$\frac{55\,520\times60}{57}=58\,400\ \text{m}^3$$

or 29 200 m^3/stove.
which produces $29\,200\times2{\cdot}07=60\,440$ m^3/h of waste gases, which is more or less the same as the figure used in the preliminary calculations.

Appendix 2

Combustion with 800 cal/m³ blast-furnace gas

Analysis, %

CO_2	13·6
CO	25·0
H_2	1·4
N_2	60·0
	100·0

For 1 m^3 of dry gas 0·034 m^3 of H_2O be added and 10 cal/m^3 for the sensible heat.

Air necessary for combustion

The amount of oxygen necessary for combustion is

$$O_2=\frac{0{\cdot}250+0{\cdot}014}{2}=0{\cdot}132\ \text{m}^3$$

The volume of air including 10% excess is

$$\frac{0{\cdot}132\times100\times1{\cdot}10}{21}=0{\cdot}690\ \text{m}^3$$

Volume composition of waste gases

CO_2 $=0{\cdot}136+0{\cdot}250=0{\cdot}386$
H_2O $=0{\cdot}004+0{\cdot}034^*=0{\cdot}048$
$N_2+O_2=0{\cdot}600+(0{\cdot}690-0{\cdot}132)=1{\cdot}158$

1·592 m^3

Sensible heat of waste gases at 1250°C

CO_2 $=0{\cdot}386\times687=265$
H_2O $=0{\cdot}048\times532=26$
$N_2O_2=1\,158\times428=496$

787 cal

The theoretical combustion temperature is

$$1\,250\times\frac{801}{787}=1\,272°\text{C}$$

Equivalent finally to an effective temperature of:

$$1\,272\times0{\cdot}95=1\,208°\text{C}$$

* Water vapour from moist gas.

The rolling of iron and steel

The rolling of iron and steel, 1955–1960 which is no.15b in The Institute's Bibliographical Series, is now ready, at a cost of 30*s* to members and 40*s* to others. The two earlier bibliographies under this title covered the period 1920–1954; the closing date of the present one is about the end of 1960.

Because of the change of emphasis in rolling operations, much material has been included on the electrical aspects of rolling mills, on gauge measurement and control, and on automation. There is also a section on the manufacture of seamless tube and on the use of the rolling process for various novel methods of plastic shaping.

Some 2 000 references, with abstracts, have been included, and there is a comprehensive index to these, to textbooks, and to the appropriate BISRA reports. Copies are available from the Secretary of The Iron and Steel Institute.

Integrated hot blast stove/gas turbine cycles

C. Rounthwaite, B.Sc., Ph.D., A.M.I.Mech.E.

SYNOPSIS

A new cycle for the production of the hot blast supply to blast-furnaces is described. The cycle replaces the conventional boiler capacity and turbo-compressor system by the introduction of a gas turbine, integrated with the Cowper stoves.

Calculations show that the overall fuel consumption for the gas-turbine system will be appreciably lower than for the conventional one. The hot blast stove/gas turbine installation will be very compact and the stoves themselves will be about one-third of the size of those in the corresponding conventional system. Smoother and more efficient combustion of the blast-furnace gas, due to the elevated pressure in the combustion chambers, is a further advantage.

The blast-furnace gas will have to be cleaned to a higher standard than is customary at the moment, and a complex, fully automatic control system will have to be evolved for the whole plant. 2013

INTRODUCTION

The use of gas turbines burning blast-furnace gas has become established in a number of iron and steelworks at Dudelange, Luxembourg,[1] Baracaldo, Spain,[1] Couillet and Seraing, Belgium,[2] and at Shelton, England.[3] These units produce electrical power, or alternatively supply compressed air to be fed to blast-furnace hot blast stoves. The gas turbine sets are very compact, simple in operation, quick starting, and give long periods of trouble-free running, providing the gaseous fuel is cleaned to higher standards than is customary in iron- and steelworks.

For many years the attractiveness of a gas turbine cycle directly producing the hot blast supply to blast-furnaces has been realized, since such a system would eliminate both the boiler capacity, and the turbo-compressors of the corresponding conventional blowing system. Various schemes for doing this have been developed, in particular those of BISRA in conjunction with Power-Jets Ltd,[4] where the final heating of the air was performed in a recuperator. When the schemes were first studied in 1954, it appeared that 750°C would be a realistic blast-air temperature for future blast-furnace requirements, and it was felt that the development of a stainless steel recuperator for this condition, although costly and difficult, would be feasible. Later, however, it appeared that future blast temperatures would rise to at least 900°C, beyond the range of practical metal recuperators, and therefore the project was dropped.[5] The above difficulty can now be overcome by the integrated hot blast stove cycle,[6] described in detail in this paper.

DESCRIPTION OF CYCLE

The single compressor version of the cycle will be explained with reference to Fig.1*a*. Air is first compressed in the main compressor *A* of the gas turbine to a pressure slightly in excess of the required blast pressure. It then passes into recuperator *B* heated by the turbine-exhaust gases. The air flow is then divided, some passing into the high-temperature regenerator (conveniently shown as *C* in the diagram), where it is heated to the required blast temperature. The other portion of the air is again split, some being fed into a high temperature (ht) combustion chamber *D* for the hot gas supply to the regenerator, while the remainder passes to a low temperature (lt) combustion chamber, *E*, whose exhaust gases mix with the regenerator waste gases, both being at about the same temperature, before passing into the turbine *F*. To compensate for the pressure-loss in the gas-side of the stoves a restriction *H* must be inserted in the air line to the low temperature combustion chamber. The outlet gases from the turbine are fed directly into the gas-side of recuperator *B*. The gaseous fuel for the two combustion chambers is compressed in a separate blower *G* driven off the main turbine shaft.

A modification to the cycle is shown in Fig.1*b*. Here the air for the two combustion chambers is compressed to a greater pressure than the blast air, which necessitates an additional compressor *J* and heat exchanger *K*.

The regenerator would in all probability be of the multi-stove Cowper type (this will be assumed during the remainder of the paper), though a continuous pebble regenerator could be used to advantage. The gas temperature entering the recuperator is adjusted so that low alloy, chrome–molybdenum steel or possibly mild steel construction can be employed. The above cycle may appear complex, but actually it employs no more components than a normal hot blast stove valve regenerator (as shown above the dotted line in Fig.1*a*), together with a recuperative blast-furnace gas-burning gas turbine (shown below the dotted line). The main difference in the hot blast stoves of this cycle compared with conventional ones is that their gas-sides operated under pressure. A number of advantages accrue from this. First, useful work can be obtained from the waste gases by expansion in the turbine, thus improving cycle efficiency. Furthermore, as the combustion chambers operate under pressure, combustion problems such as flame instability and incomplete combustion become very much reduced. Finally, due to the high pressure in the gas-side of the stoves, more compact heat transfer surfaces are possible in the matrix for a given duty.

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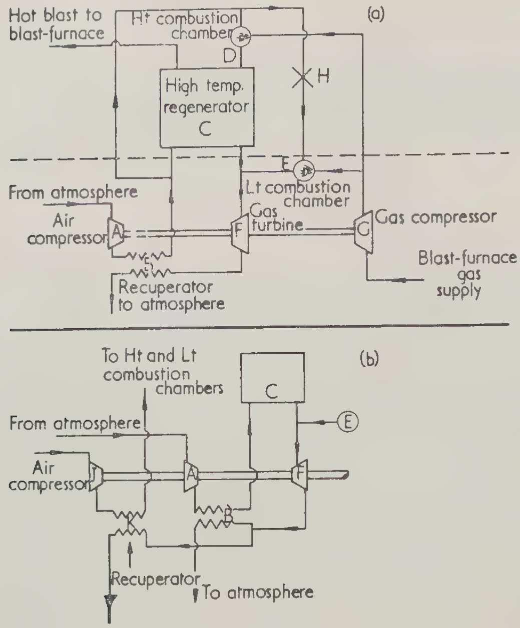
The author is research manager at Head Wrightson and Co. Ltd, Thornaby-on-Tees, Yorkshire.



a single compressor cycle
b dual compressor cycle; the remainder of cycle as in (*a*)

1 *Flow diagrams for gas turbine cycles*

TABLE I Assumed conditions for cycle calculations

Atmospheric conditions	Pressure	147 lb/in^2 abs.
	Temperature	20°C
Blast-furnace gas	Composition	27%Co, 2%H_2, 11%CO_2, 60%N_2
	Net calorific value	91·2 Btu/n ft^3
Air compressor(s)	Adiabatic efficiency	85%
	Air leakage	2%
Recuperator(s)	Air-side pressure drop	2% of abs. pres.
	Gas-side pressure drop	2% of abs. pres.
Ducting pressure loss (recuperator to ht combustion chamber)		1 lb/in^2
Hot-blast stove (assuming three-stove system)	Air-side pressure drop	1 lb/in^2
	Gas-side pressure drop	0·5 lb/in^2
Ht combustion chamber	Overall pressure drop, air inlet to gas outlet	1·5 lb/in^2
	Excess gas pressure, over air inlet pressure	2·0 lb/in^2
Lt combustion chamber	Overall pressure drop, air inlet to gas outlet	1·5 lb/in^2
	Excess gas pressure over air inlet pressure	2·5 lb/in^2
Gas turbine	Adiabatic efficiency	86%
	Total mechanical loss	2% of turbine power
Blast-furnace gas compressor	Adiabatic efficiency	83%
	Gas leakage	0

CYCLE CALCULATIONS

To perform realistic cycle calculations, it is necessary, in the first place, to specify the final blast temperature* and pressure, as well as the calorific value and composition of the blast-furnace gas fuel. It is also necessary to choose appropriate values for the performance of all the rotary components, i.e. adiabatic efficiency, mechanical, and leakage losses; together with the typical values for the pressure drop across the heat-exchanger equipment, ducting and combustion chambers. Important temperatures from practical considerations are those of the hot gases at inlet to the hot blast stoves, i.e. corresponding to the dome temperature, and the gases at inlet to the recuperator, and for any calculation these have to be suitably fixed together with the recuperator effectiveness.† In the case of the dual-compressor cycle, it is also necessary to specify the delivery pressure of the second compressor and the effectiveness of the corresponding recuperator.

The cycle calculations can now be performed by computing in the first place the pressure and temperature of all the various points in the cycle. If the total weight of air passing to the two combustion chambers per lb of blast air-flow is taken to be a dependent variable, it is then possible on performing heat balances across the stoves and the combustion chambers to deduce in terms of this variable the flows in all the other circuits. Finally, by solving an equation for power balance of the rotary components, the precise value of this variable can be found, and hence all the proportional gas and air-flow rates in the cycle are determinate. The total blast-furnace gas consumption per lb of blast air produced, is a measure of the 'efficiency' of the cycle (the lower this value, the more efficient the cycle). Finally, if the required blast air-flow is specified the power of all the rotary components can easily be deduced. The arithmetic of such calculations is tedious, and has been performed on a computer.

In the calculations given in this paper, the blast air temperature has been taken to be 1000°C (except for the fourth set of calculations), and the blast-pressure to be 30 lb/in^2 gauge (except for the third set), the dome temperature being fixed at 1300°C (except for the fourth set). All the other assumed data for the calculations are given in Table I.

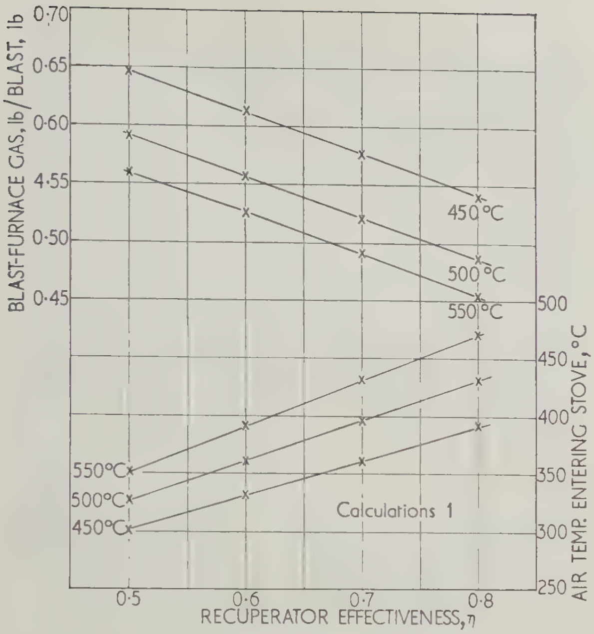
In the first set of calculations performed on the single compressor cycle four recuperator-effectivenesses (0·5, 0·6, 0·7, and 0·8) have been considered, each with three different inlet recuperator gas temperatures (450, 500, and 550°C). The results of the computations are shown graphically in Figs.2 and 3. In Fig.2, the total blast-furnace gas consumption per lb of blast air and also the air inlet temperature to the hot blast stove are both plotted against recuperator effectiveness, while in Fig.3 the total air compressed and also the air to the low temperature combustor, each per lb of blast air, are similarly plotted against recuperator effectiveness.

The dual compressor cycle is considered in the second set of computations where the second compressor outlet pressure is changed in four steps from 46·6 lb/in^2 abs. to 82·2 lb/in^2 abs. Both recuperators are taken to have an effectiveness of 0·6 while the inlet gas temperature to each is assumed to be 500°C. In Fig.4 the total fuel consumption and the turbine inlet temperature are both shown plotted against delivery pressure to the second compressor, while in Fig.5 proportional air flows have been plotted against the same variable.

In the remaining two sets of calculations only the single compressor cycle is considered, the recuperator effectiveness being fixed at 0·6 and the gas inlet temperature to it at 500°C. For the third set the blast pressure has been raised to 40 lb/in^2 gauge, corresponding to high top-pressure operation of the blast-furnace. In the fourth set the effect of higher blast

* In a three-stove system this is the 'straight-line temperature' after the entry of the mixing air.

† Recuperator effectiveness is defined as the ratio of air-side temperature rise to the difference between gas and air inlet temperatures.



Turbine inlet temp. for 450°C recuperator, gas inlet temp. = 626°C
Turbine inlet temp. for 500°C recuperator, gas inlet temp. = 688°C
Turbine inlet temp. for 550°C recuperator, gas inlet temp. = 750°C

2 *Fuel consumptions and blast inlet temperature against recuperator effectiveness for 450, 500, and 550°C recuperator gas inlet temperatures*

temperature has been explored. In this case, a blast temperature of 1200°C has been considered, with a dome temperature 1400°C; the blast pressure being fixed at 30 lb/in^2 gauge. The results of these last two sets of calculations are given in Table II.

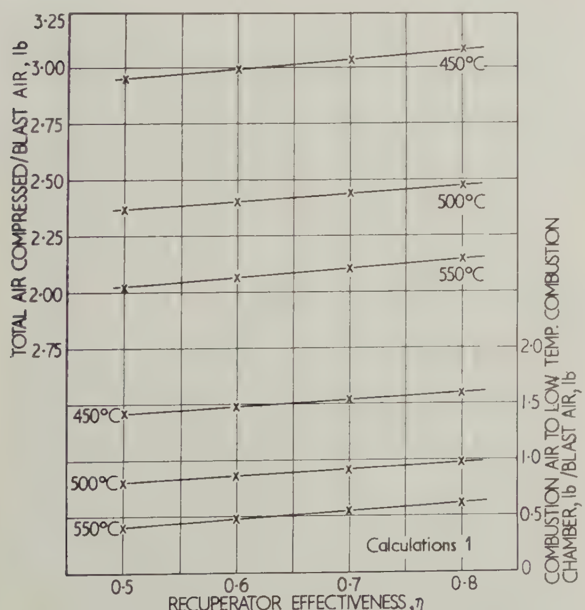
DISCUSSION

The results clearly show (*see* Fig.2) that the blast-furnace gas consumption per lb of blast air, progressively decreases with the increase of recuperator-effectiveness, and also with increase of inlet gas temperature to the recuperator. Further improvement of fuel consumption can be obtained by using the dual compressor cycle with the second compressor operating at much higher delivery pressures than the blast pressure (*see* Fig.4).

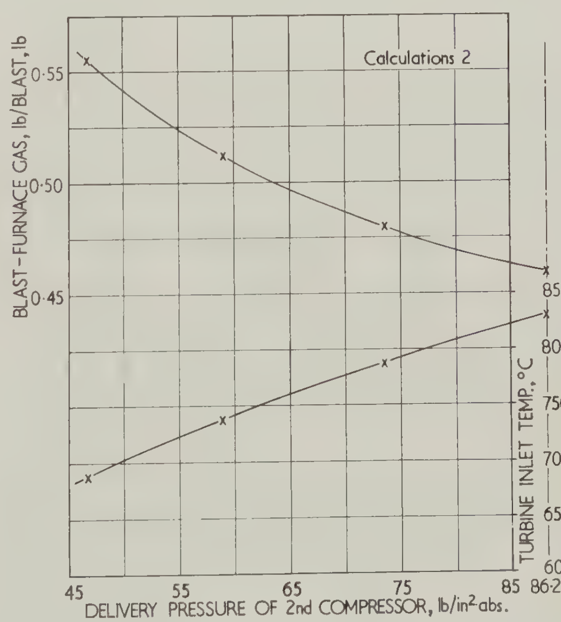
It is interesting to compare these fuel consumptions with the corresponding values for the conventional turbo-blower system. In estimating the latter, the blast-furnace gas consumption in the boilers producing the steam has to be added to that burnt in the hot-blast stove combustion chambers. To get a fair comparison for the modern conditions, relatively high values have to be chosen for boiler, turbine, blower, and stove efficiencies of the conventional system. The assumed data and the estimated fuel consumptions for three blast and dome conditions are given in Table III. Comparing these consumptions with corresponding values for the single compressor gas turbine system, using a moderately-rated recuperator (i.e. effectiveness 0·6 and inlet gas temperature 500°C), it can be seen that the gas-turbine system fuel consumption will be between 0·855 and 0·9 of the values for the conventional system, a distinct advantage for the gas turbine. Greater reductions in fuel consumption are possible with the dual compressor cycle.

TABLE II Results of calculations 3 and 4

	Calculation 3	Calculation 4
Conditions		
Hot blast { Pressure, lb/in^2 gauge	40	30
Hot blast { Temperature, °C	1 000	1 200
Gas inlet to stove, temperature, °C	1 300	1 400
Results		
Blast-furnace gas, lb/lb, blast air.	0·564	0·651
Air temperature entering stove, °C	373	362
Gas temperature at inlet to turbine, °C	730	688
Total air compressed/lb, blast air.	2·31	2·302
Air to lt combustion chamber,/lb, blast air.	0·721	0·737



3 *Proportional air flows in circuit against recuperator effectiveness for 450°, 500°, and 550°C recuperator gas inlet temperatures*



4 *Fuel consumption and turbine inlet temperature for dual compressor cycle. Recuperator effectiveness 0·6 throughout*

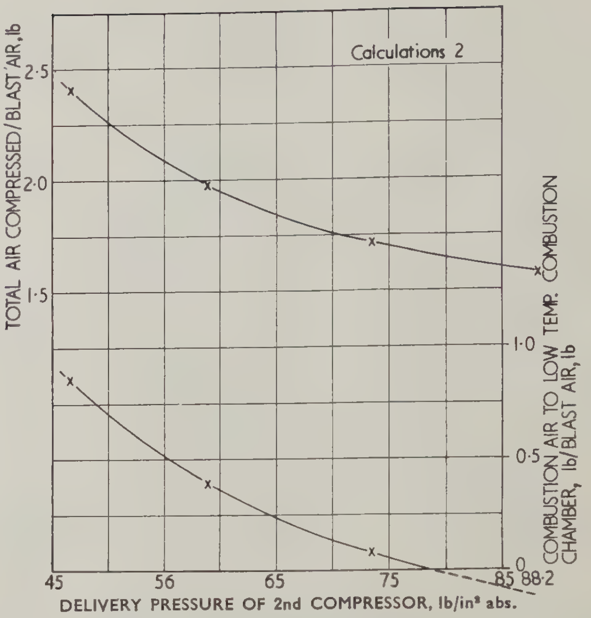
TABLE III Fuel consumption of conventional turbo-blower system

Assumed values			
Air inlet temperature to stoves	100°C		
Stove thermal efficiency, %	85		
Boiler thermal efficiency, %	87		
Turbine overall thermal efficiency, %	34		
Mechanical efficiency of blower drive, %	98		
Blower adiabatic efficiency, %	85		
Conditions			
Corresponding gas turbine calculations	*1, 2*	*3*	*4*
Hot blast: Pressure, lb/in² gauge	30	40	30
Hot blast: Temperature, °C	1 000	1 000	1 200
Gas inlet to stove, temperature °C	1 300	1 300	1 400
Fuel consumptions/lb, blast air.			
Blast-furnace gas burnt in boiler, lb	0·196	0·233	0·196
Blast-furnace gas burnt in combustion chambers, lb	0·425	0·425	0·527
Total blast-furnace gas, lb,/lb, blast air.	0·621	0·658	0·723

The total air compressed per lb of blast, gives directly the measure of the size of the compressor and turbine. Examination of the results given in Figs.3 and 5 show that it is reduced with increase of recuperator gas inlet temperature, i.e. resulting from a rise of turbine inlet temperature, and also with increase of compressor ratio in the case of the dual compressor cycle. Calculations for the latter cycle indicate that at at the highest pressure ratio considered, there will be no need for any air supply to the low temperature combustor, a small amount of surplus power will also be available from the turbine. Under these conditions it might be possible to eliminate this combustion chamber. However, in actual operation other means must be provided in order to keep the turbines running during the start-up and stove changeover periods.

A further advantage for the gas turbine system can be deduced from the cycle calculations. It is that the surface area and size of the stoves will be very much smaller than conventional ones. This arises from two factors, the first being that the air entering the stove system is considerably raised in temperature by heat received in the recuperator. The main factor, however, is that owing to the high waste gas temperature from the stoves the effective 'temperature driving force' across them is greatly increased. Calculations for the first condition given in Table III, show that in the single compressor gas turbine system with a moderately rated recuperator (as in first paragraph of discussion), the stove surface area would be about one-third of the area for the corresponding conventional system. It should be emphasized that this large reduction will not result in a proportional saving in high temperature bricks in the gas turbine cycle stoves, since the main economy will be at the lower temperature end. Nevertheless, there should be some economy in such bricks resulting from the employment of smaller passages in the case of the gas turbine system.

It must not be forgotten that in spite of the reduction in the regenerator surface, additional surface must also be provided in the recuperator. For the conditions just considered, in which a recuperator of 0·6 effectiveness is employed, its surface area will be about 43% of the total stove surface area of the gas turbine system. As the heat exchanger is of metal construction, a more compact type of surface can be used, and preliminary design calculations indicate that this component is not likely to be unreasonable in size in comparison with other components of the system.



5 *Proportional air flows in circuit for dual compressor cycle. Recuperator effectiveness 0·6 throughout*

CONCLUSIONS

A hot blast stove/gas turbine cycle would appear to offer the following advantages over the conventional turbo-blower stove system, for supplying hot blast to blast-furnaces:

(1) the whole installation will be very compact, eliminating long pipe runs between the turbo-blower and the hot blast stoves
(2) the stoves of the turbine system will be much reduced in size compared with conventional ones, and there should be some reduction in the amount of high-temperature refractory brick in them when higher blast temperatures are required
(3) the combustion chambers for the stoves operate under elevated pressure, which should give rise to smoother and more efficient combustion
(4) the gas turbine system will be appreciably more economical in the amount of blast-furnace gas burnt, compared with the conventional system: a most important factor since the largest portion of the running cost of conventional plants (including capital depreciation), is fuel cost.[8]

As far as can be seen at the moment, the system will give rise to the following problems:

(1) the blast-furnace gas used will have to be cleaned to a higher standard than is customary in iron- and steelworks at the moment
(2) gas turbines are generally costly primovers, particularly when including an exhaust recuperator
(3) a complex control system would be necessary, e.g. the compressed air delivery in the case of the single compressor cycle has to be split in definite proportions into three streams, and in addition the conditions at turbine entry must be maintained correct during stove changeover.

With regard to the first problem, experience on the

Couillet gas turbine plant,[7] showed that considerable difficulties were experienced with fouling, when the dust content of the blast-furnace gas was 0·0068 gr/n ft^3. However, when additional electrostatic precipitators were installed, cleaning the gas down to 0·00087 gr/n ft^3, trouble-free running has been possible over long periods, e.g. 25000 h. It is felt that probably in our application, the gas would not have to be cleaned as much as in the above plant, due to the absence of intercoolers on the gas compressor. In connexion with plant costs, from cycle considerations a number of likely conditions will first have to be selected, and preliminary designs then undertaken for costing purposes. In this way, it should be possible to determine if the turbine and recuperator costs can be offset against savings resulting from the simplicity of the rest of the system.

In connexion with the control of such a plant, owing to its complexity it would seem that a fully automatic control system would have to be evolved. This appears to be the most difficult of the technical problems yet to be overcome for successful exploitation of the hot blast stove/gas turbine cycle.

ACKNOWLEDGMENTS

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Historical note no. 8 (second series)

Transmutation of iron into copper

H. R. Schubert

THE BELIEF in the transmutation of metals was a favourite idea of medieval alchemy.[1] It survived well into the 17th century, which in science is marked as a turning point from medievalism to modernity.

A period such as in 16th-century England in which the demand for copper increased considerably without meeting with sufficient supply, was a fertile ground for a revival of the old idea of transmuting iron, which still ranked as a base metal, into the more valuable copper. It is not to be wondered at that influential persons and even the leading statesman of Queen Elizabeth I, William Cecil, Lord Burghley, the great promoter of all industrial enterprises, for the sake of making the country economically independent and strong in defence, became interested in a project for transmuting iron into copper. An initial attempt was made in the London house of Sir Thomas Smith, Secretary of State (1513–77) and afterwards at his country seat at Saffron Walden, Essex, in 1571. Under his auspices, William Medley experimented with converting iron into copper with the help of vitriol. The method employed, however, proved to be too expensive for any profit. Subsequently the works were removed to Winchelsea and afterwards to Poole, Dorset, where land was leased from Lady Mountjoy for £300 per annum. In 1574, a 'Society of the New Art' was founded, to which (apart from Smith) Lord Burghley, the Earl of Leicester, and Sir Humphrey Gilbert belonged, each of whom contributed £100 to bear the expenses. The works was removed to the Isle of Anglesey. Medley undertook to make 500 tons of 'perfect copper' out of 600 tons of raw iron, but, urged to disclose the achievement, Medley and his partner, Topcliff, caused one delay after another, constantly demanding more investments. As a result, Smith and Gilbert lost great sums of money. Medley became 'beggared' and was imprisoned in 1576.[2]

The fate of Medley constituted no lasting deterrent. In 1637, a Captain Thomas Whitmore obtained a patent from King Charles I for making vitriol out of copper and for 'preparing and drawing water from copper-ore by which to make copper out of iron' for 14 years.[3] A practical achievement, however, was not attained.

The failures of enterprises to realize new inventions were so numerous that it became almost common knowledge that they were only projects to extract money from wealthy and influential people interested in technical novelties. In a pamphlet of 1641, the 'projector' was ridiculed by calling him 'the very corne-cutter of the age, wherein he lives, and hath a notable fault in the unsteadinesse of his knife into the tender parts of a common-wealth . . . and never leaves untill he have brought out the very coare of their purses.'[4]

On the other hand, it must not be forgotten that often a serious striving was the moving force. Even the great English natural philosopher and chemist, Robert Boyle (1627–91) frequently called the 'father of modern chemistry' considered the transmutation of metals not impossible and performed experiments in the hope of effecting it.[5]

This note was received earlier this year. Dr Schubert died on 9 July, and an obituary appears on p.76 of this issue.

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Developments in ironmaking and furnace design at Appleby-Frodingham, from an engineering aspect

Arthur Bridge

SYNOPSIS

The paper deals briefly with ironmaking at Appleby-Frodingham before 1945, then records 15 years of phased development. Furnace design, progress, and problems are considered from an engineering aspect, and the paper concludes with a note on iron and slag disposal and future developments. 1995

INTRODUCTION

TO DEAL FULLY WITH ironworks development at Appleby-Frodingham, from whatever aspect, would necessitate writing a book, not a paper, and as such a book has already been published covering the period 1863 to 1944[1] I would recommend the reader to refer to it in conjunction with this paper, as it presents a comprehensive and lucid account of the history, development, troubles, and progress of ironmaking within the company before 1945. With this in mind, this paper is generally restricted to developments from 1946 to 1961, a period during which the progress relative to ironmaking has, to put it mildly, been exceptional.

Although the main objective of the paper is a review of blast-furnace development from an engineering aspect over the past 15 years, it is nevertheless necessary to recap a little on the period before 1946, and also to look occasionally into the field of ore preparation, in order to show the effect of the latter on furnace output and design.

How things got the way they are

Following pilot experimental work on the treatment of local fines and the drying of Northants stone, a full-scale two-pan Greenawalt sintering plant and a static ore drying plant were installed at North Ironworks in 1934, and in 1937 two further pans were added to the sintering plant. This early venture into the field of sintering and ore drying was the forerunner of extensive ore preparation plants referred to later in the paper.

September 1939 brought to fruition the first major development in ironmaking at Appleby-Frodingham with the commissioning of the South Ironworks; a two-furnace plant complete with ancillaries together with a large ore preparation plant (Fig.1). The furnaces had a hearth diameter of 22 ft and were at that time the largest in the world outside the USA. From then until 1946 there is little of importance to record in the way of ironworks development, beyond stating that schemes of a very comprehensive nature were under consideration for the time when the war ended. 1946, therefore, saw the company with a total of ten blast-furnaces located in three separate plants, namely Frodingham Ironworks, North Ironworks, and South Ironworks, and from Fig.2 it will be seen that only two of these ten furnaces had identical lines.

At this stage it is worth noting that for 1946, the total ironmake from nine of these furnaces (no.3 being out of commission) was 694920 tons. Compare this with the total ironmake for the year 1960, where the four large furnaces at South Ironworks (Frodingham and North furnaces having been scrapped as redundant in 1954) alone produced 1502890 tons, and the magnitude of post-war development will then be appreciated. All this was from home ores with a self fluxing burden of 65% Frodingham and 35% Northants. With an average wet sample analysis as given in Table I, this mixture in the furnace gives a slag volume of 26 cwt/ton of iron produced.

Having briefly noted the progress made relative to ironmake over the period 1946–61, let us now see how this came about. The operation of ten blast-furnaces on three different sites was neither satisfactory nor economical, therefore in 1946 a comprehensive scheme was drawn up for the ultimate concentration of ironmaking in one plant, i.e. South Ironworks, and early in 1947 approval was given to proceed with the detailed design for stage one of this scheme.

Stages in developments at Appleby-Frodingham have already been widely published[2] and it is only necessary here to summarize the phased development relative to ironmaking. This is covered below under four separate stages.

Stage 1 1947–51

Apart from the ultimate objective of concentrating ironmaking in one plant, it was at this time considered essential to raise the output capacity of the nine furnaces then in blast to around 900000 tons/year in order to keep in step with planned developments for other sections of the works. To meet this demand it was decided that the immediate answer was a further

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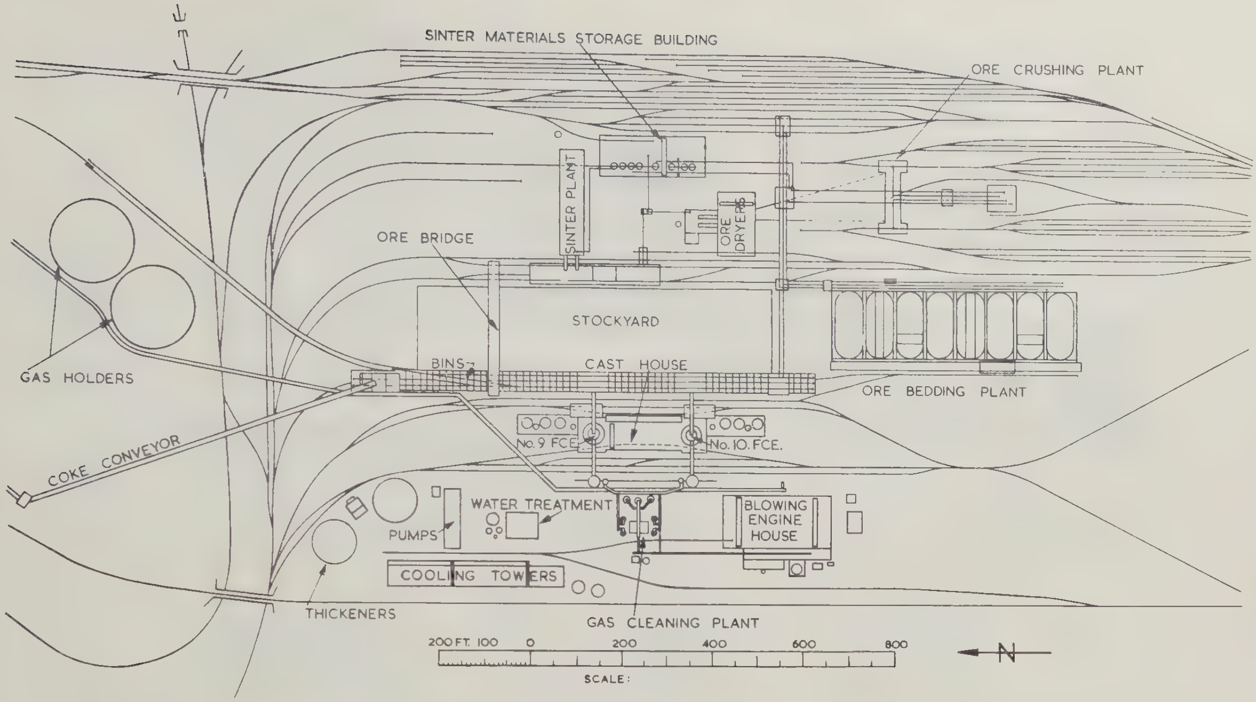
The author was ironworks engineer at Appleby-Frodingham until he retired on 30 June 1961.



1 *South Ironworks, 1939 (By courtesy of Wm. A. Haven:* Steel, *1938)*

improved furnace burden, and design work for the project, constructed under the code name 'Apex' began in May 1947. The design epitomized all our past practice, together with the application of the knowledge gained over a number of years from much experimental work. Interlocked with the existing ore preparation plant commissioned in 1939, the project included two more ore beds, four more rotary driers, another pair of continuous sintering machines (B plant), four coke grinders (rod mills), four tertiary ore crushers (hammer mills), together with the reorientation and increase of screening facilities, all as shown in black in Fig.3. The project, completed in April 1951, also included two further batteries of coke-ovens (66 ovens in all), but these form no part of this story.

Stage 2 1951–54

Operating results following the commissioning of the Apex project were so encouraging that immediate consideration was given to the initiation of stage 2 of the 1946 scheme which embodied the eventual concentration of ironmaking in one plant.

This project constructed under the code name 'Seraphim' began in January 1952 and was virtually completed by December 1954. An extensive undertaking centred on the South Ironworks, it provided for a complete new ore preparation plant including two further pairs of continuous sintering machines (C and D plants), together with two modern blast-furnaces and all ancillary plant.

The project also embodied modern blowing equipment capable of supplying both the new and existing South Works furnaces with the required volumes and pressures to meet new techniques associated with the use of high sinter burdens. The scheme also included a system of interconnecting belt conveyors between the new and existing ore preparation plants, the whole project being as shown shaded in Fig.4. Detailed information on the project has been given by Kemp.[3]

It may be of interest to note that before embarking on the Apex and Seraphim projects our difficulties lay in the knowledge that a 22-ft hearth furnace would not make more than about 3000 tons of iron per week from the low-grade Frodingham and Northants ironstones, and the progress made over the last 15 years has developed from many controlled experiments on full production scale as well as fundamental research into the problem of sinter production from limy and siliceous ores.

In September 1951 and October 1952, anticipating the completion of the Seraphim project, nos.9 and 10 furnaces (now 'Queen Mary' and 'Queen Bess') had their hearth diameters enlarged from 22 ft to 25 ft and, therefore, with the commissioning of the Seraphim furnaces ('Queen Anne' and 'Queen Victoria') in 1954, the four furnaces having an initial capacity of 23500 tons/week, the Frodingham and North furnaces became redundant.

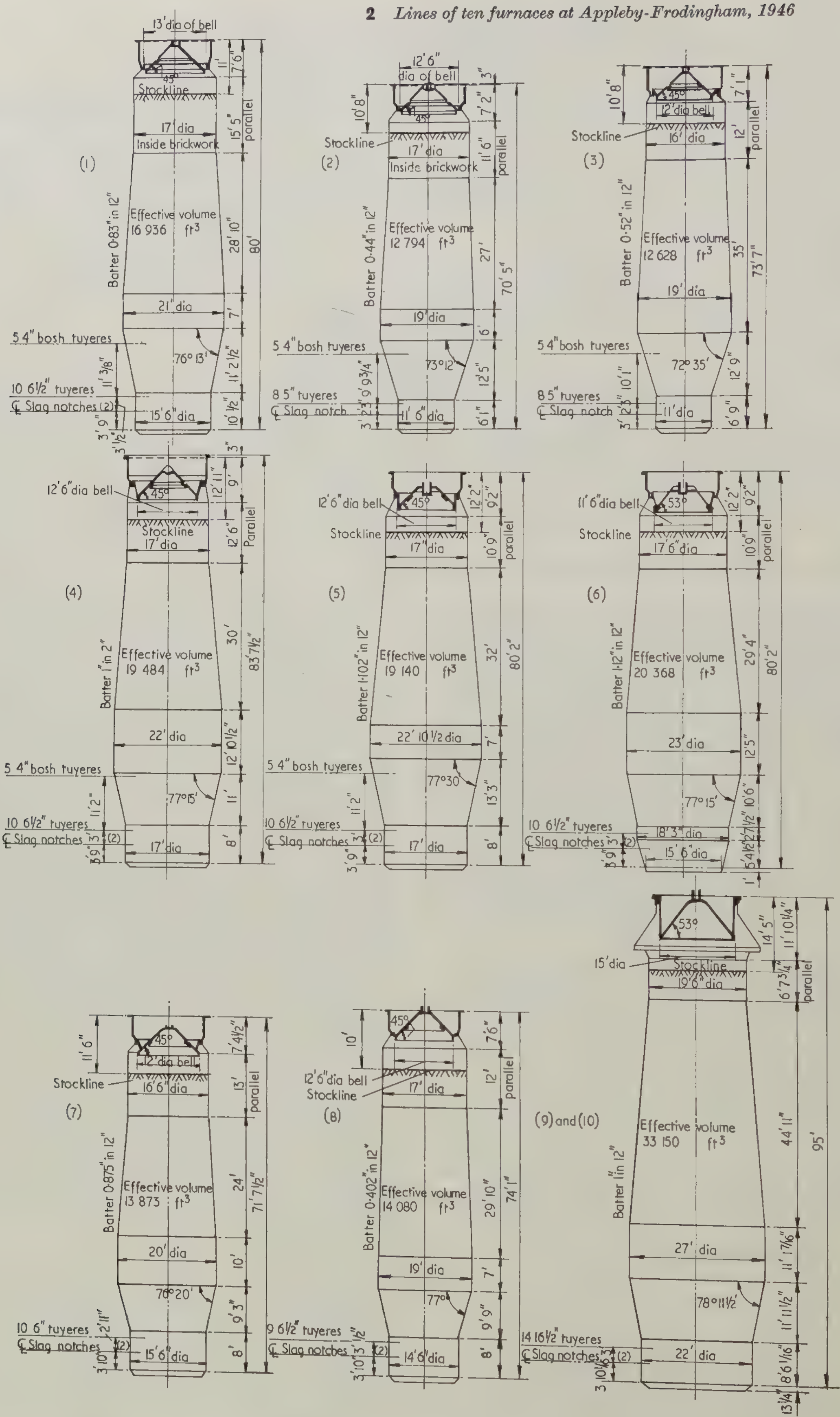
Stage 3 1954–56

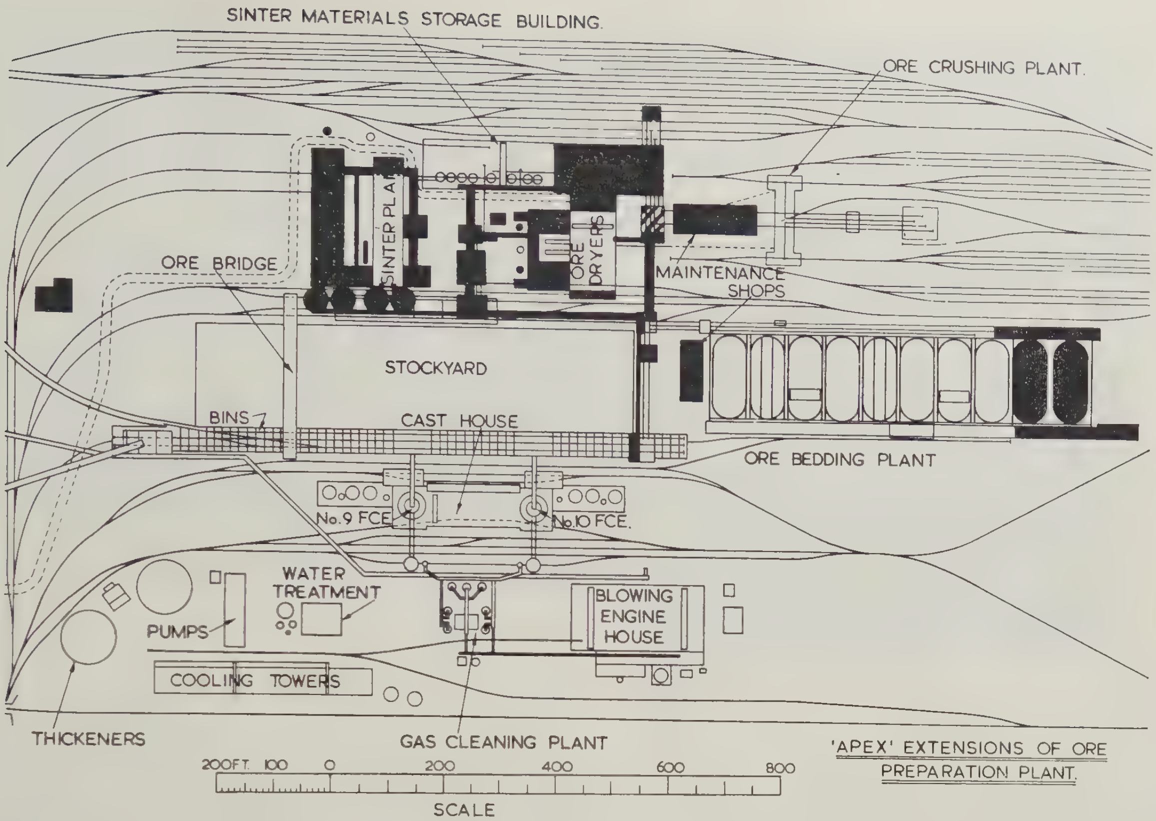
This was mainly a period of modification to the Apex plant, based on the success of the several innovations incorporated in the Seraphim project, e.g. the natural draught sinter coolers had never proved entirely satisfactory to our practice, so that authorization was given for their replacement by the Lurgi-Frodingham type of cooler recently installed at Seraphim. Similarly, the

TABLE I Wet sample analysis of ore mixture

	Frodingham, %	Northants, %
Fe	20·0	30·0
SiO_2	9·0	16·0
CaO	20·0	2·0
Al_2O_3	4·0	6·0
MgO	1·5	1·0
S	0·40	0·15

2 *Lines of ten furnaces at Appleby-Frodingham, 1946*





3 *South Ironworks, March 1951*

return fines system left much to be desired, and additional equipment was installed whereby these fines could be cooled, screened into two sizes, and returned to the raw materials feed at a controlled rate. Extensive alterations were also made to the internal screening and conveying system, in order to integrate the Apex and Seraphim plants into an economic whole, all work being completed late in 1956.

Furnace trials using Seraphim sinter revealed that given additional blast air the four furnaces had a potential of 30000 tons/week, and early in 1955 authorization was granted to install added blowing and gas-cleaning facilities. The blowing plant comprised of a 150000 ft^3/min at 35 lb/in^2 (gauge) MCR centrifugal blower for 'split wind' duty[4] (*see* Fig.5), driven by a 20000-hp turbine supplied with steam from the existing boiler plant plus an additional boiler, rated at 135000 lb/h.

This additional blowing plant necessitated the provision of further capacity for cooling the condenser circulating water and was met by the construction of a new parabolic cooling tower for gas-plant circulating water, thus releasing the gas-plant section of the original composite cooling tower for the added blowing plant water. To cope with the increased gas make from the Seraphim furnaces (Queen Anne and Queen Victoria), another precipitator (no.6) was added. Work on the above installations began in January 1955 and ended in December 1956, and these additions are shown as items '*a*' in Fig.4.

Stage 4 1956–61

Development during this period has, by and large, been concentrated on the blast-furnaces, i.e. the four Queens, Mary, Bess, Anne, and Victoria, based on the day-to-day operating experience gained with a near 100% sinter burden,[5] with an objective in mind of 100% graded sinter on all furnaces. The position, therefore, in 1956 was four large furnaces, the main features of which are given in Table II.

Before dealing with the pros and cons of furnace development and the engineering work involved, it would be useful to look at Table III which gives the main features for the same four furnaces as operating today and from which will be seen the progress made in the short space of five years.

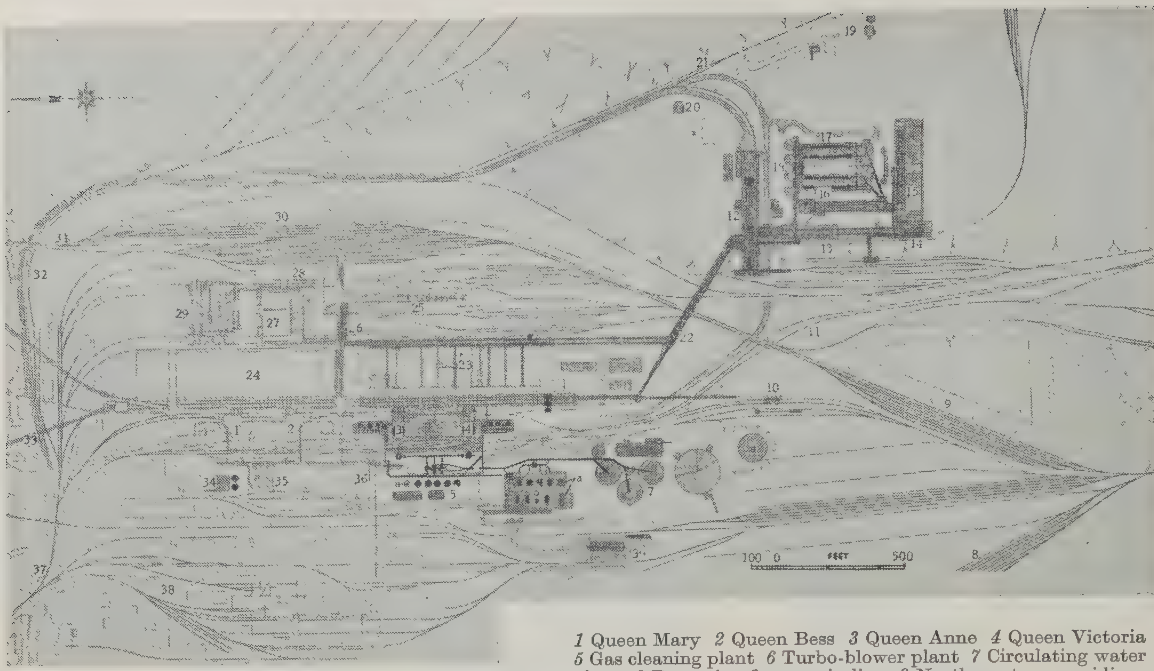
FURNACE DESIGN, PROGRESS, AND PROBLEMS

The comprehensive nature of this subject is such that for clarity, progress will be dealt with in zones under the usual terms of reference, namely hearth, tuyere-belt, bosh, stack, top-gear, uptakes, and downcomer, but before design development is described in detail, reference should be made to Fig.6 which shows the original, intermediate, and current lines for the four furnaces under review.

Hearth construction

From Fig.6 it will be seen that all hearth diameters have progressively increased, in the case of Queen Mary and Queen Bess, from 22 ft to 25 ft and then to 27 ft 6in. In the case of Queen Anne and Queen Victoria from 27 ft and 28 ft 6in respectively to 31 ft. How was this achieved?

Dealing first with Queen Mary and Queen Bess, originally known as nos.9 and 10, it is of importance to note that initially all refractories were ceramic, carbon



4 *South ironworks, July 1954*

1 Queen Mary *2* Queen Bess *3* Queen Anne *4* Queen Victoria *5* Gas cleaning plant *6* Turbo-blower plant *7* Circulating water plant *8* Reception from main line *9* Northampton ore sidings *10* Purchased coke reception *11* Slag route to bank *12* No.3 ore crushing plant *13* Tertiary screens and crushers *14* Coke pulverizing plant *15* Sinter materials storage *16* Primary mixers *17* Sinter plant (Seraphim) *18* Sinter coolers *19* Circulating water plant *20* 33 kV substation *21* Frodingham ore route (S) *22* Interconnecting conveyors *23* Ore beds *24* Stockyards *25* Nos.1 and 2 crushing plant *26* Rescreening station *27* Northampton ore dryers *28* Sinter material preparation *29* Sinter plant (Apex) *30* Frodingham ore sidings *31* Frodingham ore route (N) *32* Slag route to pits *33* Conveyor from coke-ovens *34* Water-treatment plant *35* Gas cleaning plant *36* Gas blowing engines *37* Hot metal to melting shops *38* Frodingham melting shop *39* Ironworks administration

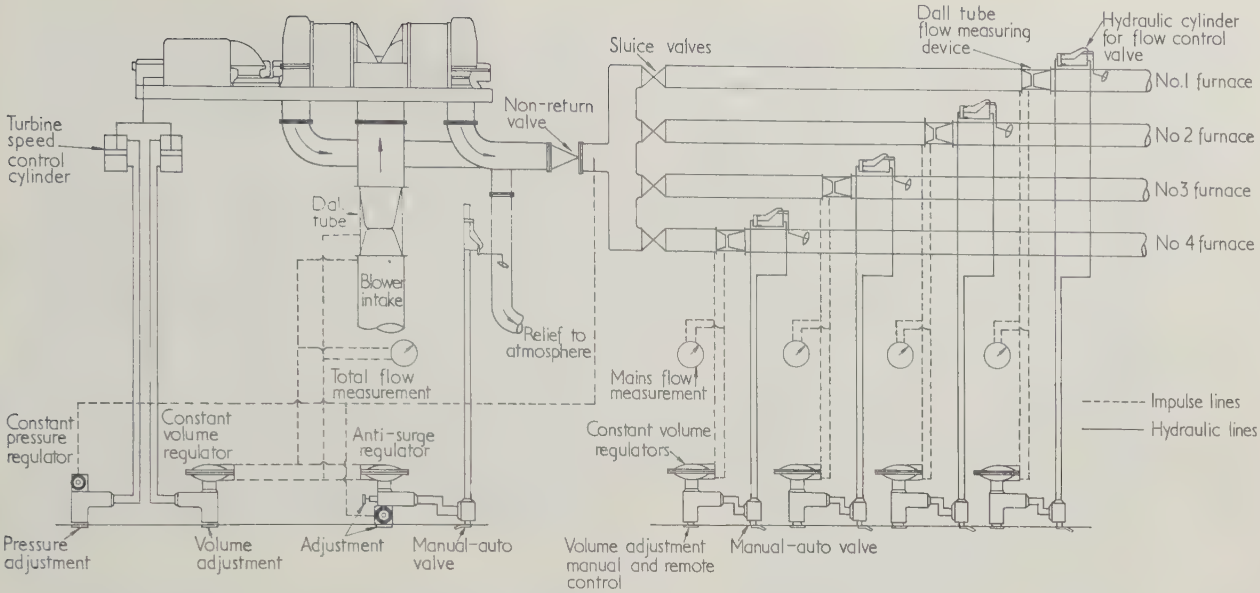
at that time being only used for such purposes as ramming between the hearth jacket and firebrick linings and the lining of runners, a method used since 1905.

These two furnaces, larger than any operated before 1939, were of McKee design, with 22-ft dia. hearths of orthodox American construction incorporating a ring of CI cooling staves, double-banked in the region of the tap-hole, and the two slag-notches. At Appleby-Frodingham internal cooling of the hearth had always been considered a potential hazard, an opinion confirmed in April and September 1941 when iron penetration of the stave coolers in nos.10 and 9 furnaces respectively, resulted in a 'breakout' through the hearth jacket in the region between the tap-hole and slag-notches. Further breakouts occurred on both furnaces in 1942 and 1943, and in May 1944, no.10 was blown out for a hearth reline, no.9 following in October for similar treatment. However, it is only fair to state that the origin of these faults was failure of the ceramic lining and not initially the cooling staves.

At this juncture internal stave cooling received serious thought; even dispensation was considered, but as we were now to install our first carbon hearth, caution prevailed, and the stave coolers were restored for a further campaign, with the difference that the

TABLE II Characteristics of the four 'Queen' furnaces operating in 1956

	Queen Mary	Queen Bess	Queen Anne	Queen Victoria
Hearth dia., ft in	25 0	25 0	27 0	28 6
Throat dia., ft in	22 0	22 0	22 0	22 0
Small bell dia., ft in	6 0	6 0	7 0	7 0
Large bell dia., (53° angle), ft in	15 0	15 0	15 0	15 0
Effective volume, ft^3	39900	39900	42370	44350
Slag notches	3	3	3	3
Hearth tuyeres	14 (12, 15in × 7in) (2, 18in × 3½in)	14 (12, 15in × 7in) (2, 18in × 3½in)	18 (16, 15in × 7in) (2, 18in × 3½in)	18 (16, 15in × 7in) (2, 18in × 3½in)
Bosh tuyeres	7 (11in × 4in)	7 (11in × 4in)	9 (11in × 5in)	9 (11in × 5in)
Hearth cooling	Spray	Spray	23 CI stave coolers	23 CI stave coolers
Tuyere-belt cooling	106 plate coolers	106 plate coolers	103 plate coolers	103 plate coolers
Bosh cooling	All furnaces spray cooled			
Stack cooling (cigar coolers)	9 rows × 21 (189)	9 rows × 21 (189)	3 rows × 27 (81)	3 rows × 27 (81)
Clay guns	Elect. rotary	Elect. rotary	13 ft^3 elect. plunger	13 ft^3 elect. plunger
Four gas offtakes, dia., ft in	5 0	5 0	5 9	5 9
Two gas uptakes, dia., ft in	5 9	5 9	7 6	7 6
One gas downcomer, dia., ft in	6 6	6 6	9 0	9 0
Bleeder valves (Baer)	2, 21in dia.	2, 21in dia.	3, 21in dia.	3, 21in dia.



5 *Schematic arrangement of controls for split-wind blowing (By courtesy of C. A. Parsons Ltd)*

double banks around the tap-hole and slag-notches were omitted, and as a second line of defence, a safety wall of two 3-in courses of carbon brick, plus a 2-in layer of ramming, was inserted between the coolers and the hearth jacket (*see* Fig.7), and provision made for spray cooling the jacket in case of necessity. Both furnaces were dealt with in the same way, and returned to service until the time was opportune for a complete reline.

As soon as possible after the war these furnaces were completely relined, no.10 being blown-out in February 1946, no.9 in the following November. During these relines examination revealed that the carbon hearth walls installed in 1944 were in excellent condition, the full 18in of carbon brick in front of the stave coolers being untouched, so much so that the bricks were recovered and used again in a later construction.

The cooling staves, and carbon safety wall behind, were not therefore disturbed on that occasion, except to renew the one stave that was cut through to allow the tapping of the salamander. The staves were, however, acid cleaned internally and pressure tested *in situ* for leaks before the 18-in carbon inwall was rebuilt.

With regard to the hearth bottom, apart from the first one or two rings adjacent to the walls, all the carbon bricks had disappeared, and as during the campaign brick-like objects had been observed floating in front of the tuyeres, there can be little doubt that the complete bottom had lifted during its life.

It is not the intention here to proceed with the story of carbon refractories, as much has already been published by specialists in this field,[6–8] all of whom include valuable information on the general application of carbon refractories in the blast-furnace.

From our vast experience with the use of carbon it is only fair to record that while it is now our standard construction for hearth, tuyere belt, and bosh walls, its use was not a complete success in the stack, and although the interlocked block construction (Fig.8) for the hearth bottom has overcome the 'flotation' problem, carbon bottoms leave much to be desired, and our next bottom is to be constructed in sillimanite.

TABLE III Present-day characteristics of furnaces shown in Table II

	Queen Mary	Queen Bess	Queen Anne	Queen Victoria
Hearth dia., ft in	27 6	27 6	31 0	31 0
Throat dia., ft in	22 9	22 9	23 9	22 6
Small bell dia., ft in	6 0	6 0	7 0	7 0
Large bell dia. (53° angle), ft in	15 0	15 0	15 0	15 0
Effective volume, ft^3	42515	42515	50838	46767
Slag notches	3	3	3	3
Hearth tuyeres	20 (18, 18in × 7in) (2, 18in × 3½in)	20 (18, 18in × 7in) (2, 18in × 3½in)	26 (24, 18in × 7in) (2, 18in × 3½in)	26 (24, 18in × 7in) (2, 18in × 3½in)
Bosh tuyeres	7 (11in × 4in)	7 (11in × 4in)	12 (11in × 4in)	12 (11in × 4in)
Hearth cooling	All furnaces spray cooled			
Tuyere-belt cooling	All furnaces stave cooled			
Bosh cooling	All furnaces spray cooled			
Stack cooling (cigar coolers)	16 rows, 336 coolers	16 rows, 336 coolers	16 rows, 479 coolers	16 rows, 479 coolers
Clay guns	13 ft^3 electric plunger	13 ft^3 electric plunger	13 ft^3 electric plunger	13 ft^3 electric plunger
Four gas offtakes, dia., ft in	5 0	5 9	5 9	5 9
Two gas uptakes, dia., ft in	5 9	7 6	7 6	7 6
One gas downcomer, dia., ft in	6 6	9 0	9 0	9 0
Bleeder valves (Baer)	2, 21in dia.	2, 21in dia.	3, 21in dia.	3, 21in dia.

It is hoped that this construction will eliminate excessive erosion and prolong hearth bottom-pad life.

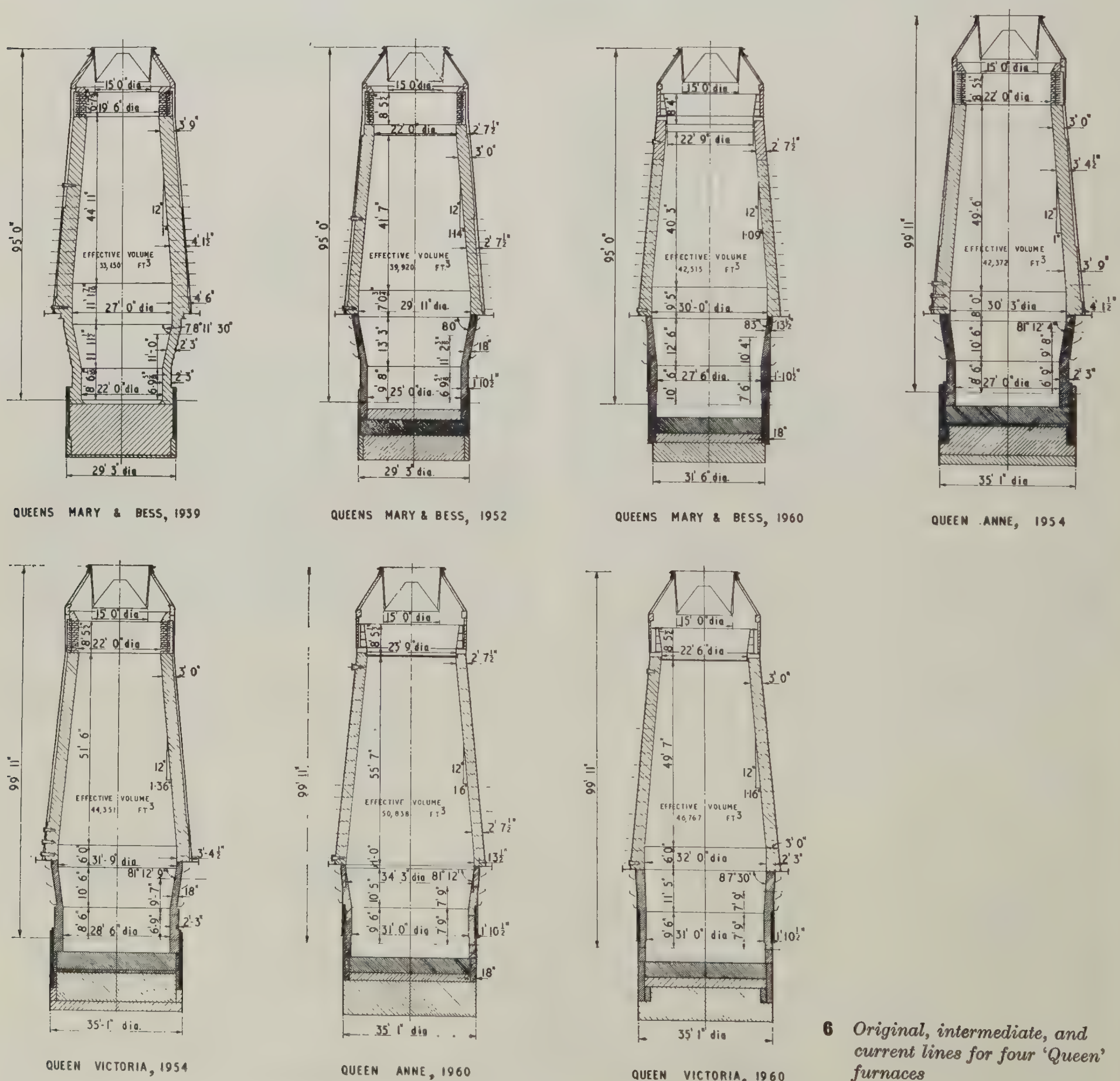
Hearth enlargement brought another spate of problems, although the initial step of increasing the hearth diameters of Queen Mary and Queen Bess from 22 ft to 25 ft presented little difficulty, as by now (1951) our confidence in carbon bricks for hearth wall construction was such that we had no fears in dispensing with the internal cooling staves and reverting to our original practice of external spray cooling for the hearth. This decision allowed the increase in diameter to be accommodated within the existing jacket without detriment to hearth wall thickness, thus avoiding the necessity to construct a new hearth jacket.

During these hearth enlargements the opportunity was taken to extend the use of carbon refractories to the tuyere-belt and bosh zones of the furnace, as much experience had by now been gained with the use of carbon in these zones in the Frodingham and North furnaces.

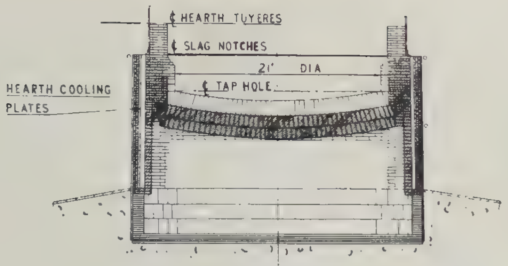
While retaining the original McKee tuyere belt plated construction incorporating plate coolers, the 'banded' type bosh construction with its plate coolers was replaced by a spray-cooled bosh jacket, an essential feature coupled with the use of carbon refractories in this region (Fig.9).

The second enlargement (1956–57) from 25 ft to 27 ft 6in was, however, a major job, as it entailed complete new hearth, tuyere belt, and bosh jackets. The construction method adopted was to burn off the existing 29 ft 3in i.d. hearth jacket at foundation level, leaving the 5 ft depth below this level *in situ*, then attach the bottom of the new 31 ft 6in i.d. jacket to the top of the old jacket by a 1-in thick annular ring mounted on a series of solid steel packs and finally grout to the existing foundation block.

The tuyere belt and bosh were of composite $1\frac{1}{4}$-in thick plate construction, offset to 32 ft 1in inside dia. and mounted on the top of the hearth jacket by a 9in × 1in thick annular ring, the internal section of this



6 *Original, intermediate, and current lines for four 'Queen' furnaces*



7 *The first carbon hearth at Appleby-Frodingham, built with British-made carbon bricks, no.10 furnace, blown in 26 June 1944*

ring forming a seating for the tuyere-belt cooling staves, and the mantle was cut back 4½in to accommodate the top of the new bosh jacket.

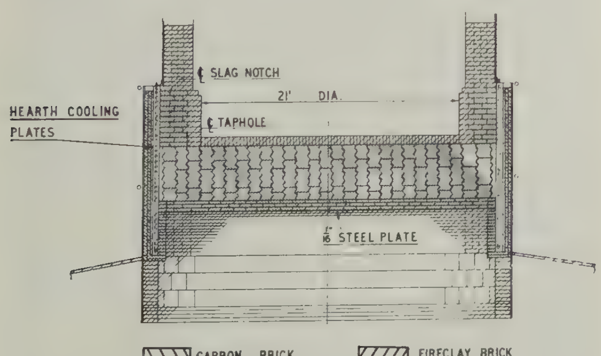
This increase in hearth diameter also necessitated the installation of a new bustle-main to accommodate the additional number of tuyeres, the mean circumferential dia. of the main being 50 ft 3in compared with the original 46 ft 6in dia. with an outside dia. 5 ft 6in in lieu of the original 4 ft 6in. The new bustle main was elevated 2 ft 3in in order to obtain a satisfactory tuyere stock arrangement (Fig.10).

This second enlargement to these two furnaces (Queen Mary and Queen Bess) is the limit permissible within the existing mantle supporting columns; anything further will necessitate a major reconstruction.

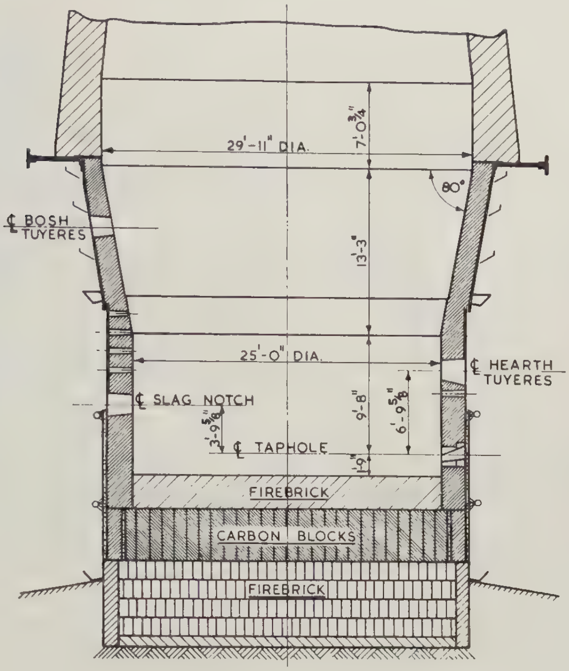
The next step taken in hearth enlargement was that for the two Seraphim furnaces Queen Anne and Queen Victoria, but before going into the details of this enlargement it is necessary to record that at the time of designing (1951) we had only one large furnace working without internal stave coolers, so that this feature was again incorporated in the original hearth construction, and it is sad to relate that during their first campaigns, stave cooler trouble occurred at each furnace, e.g. Queen Anne suffered from iron penetration of the cooler to the left of the tap-hole; Queen Victoria split her hearth jacket from top to bottom, probably owing to a 'kick' caused by a stave cooler water leakage into the hot zone.

In the case of Queen Anne, metal surgery enabled the faulty cooling stave to be removed and replaced in three sections by cutting windows in sequence in the hearth jacket, and welding-in inserts in sequence on completion of each step, as shown in Fig.11.

The case of Queen Victoria was quite different. No

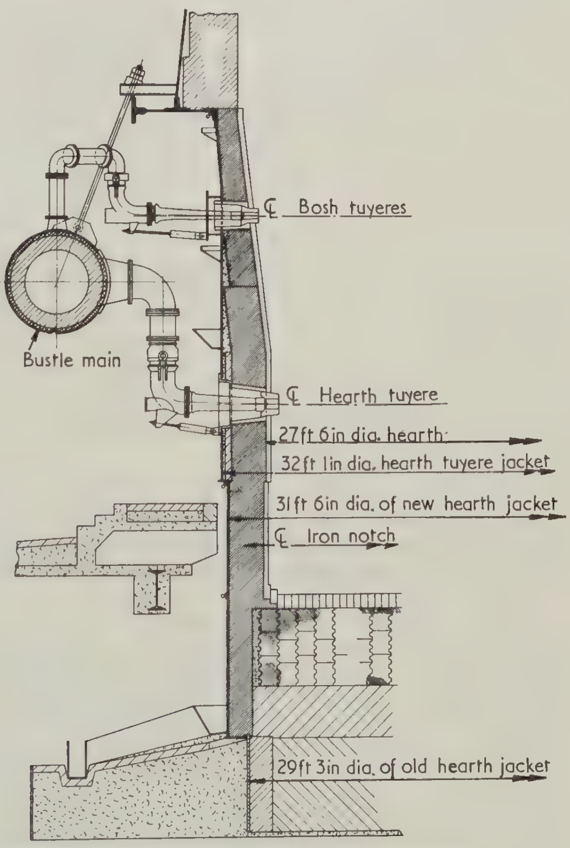


8 *Diagram showing the construction of a corrugated carbon-block hearth*

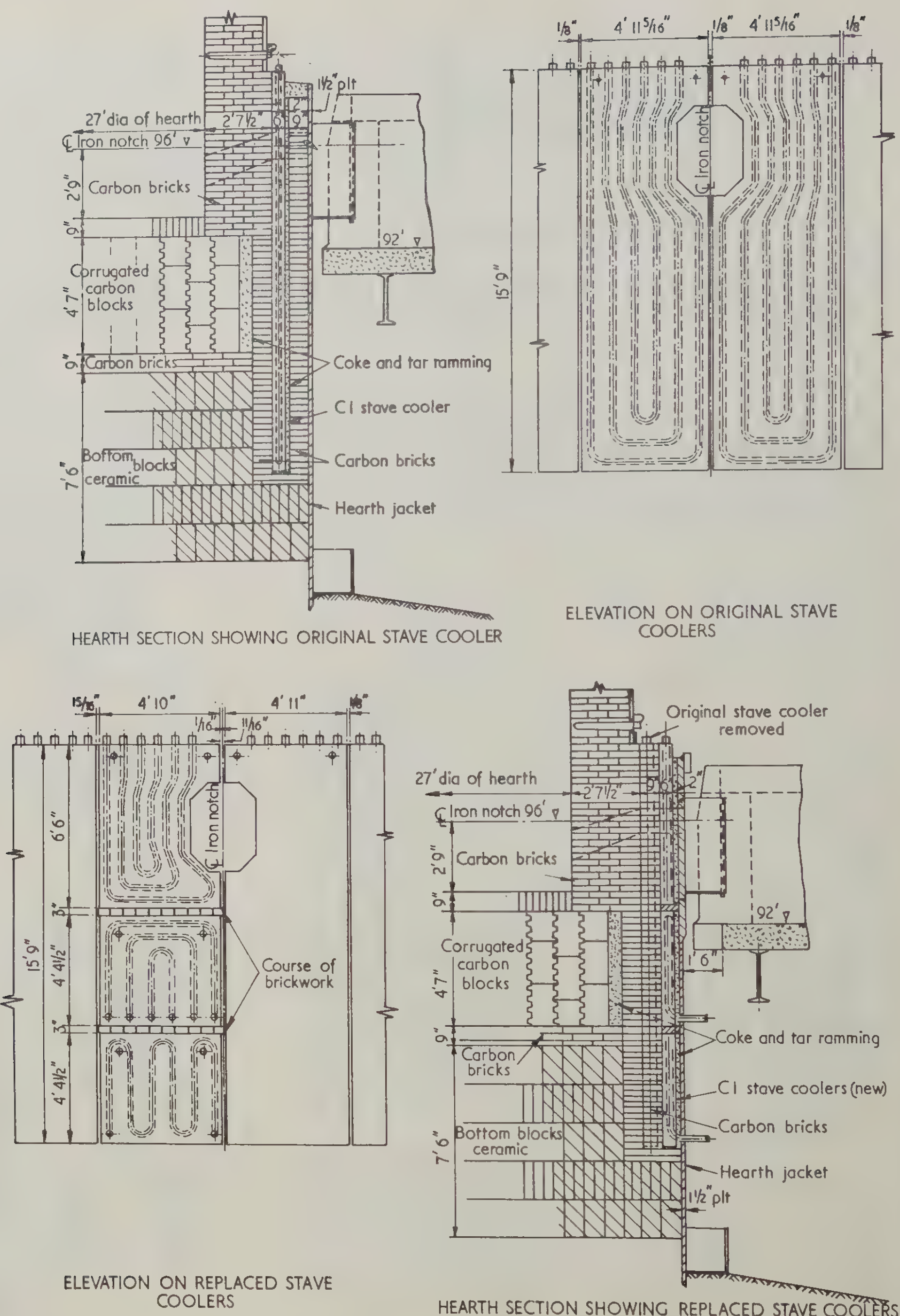


9 *Carbon hearth and bosh*

iron penetration occurred, but the hearth jacket had sprung on splitting and had to be trimmed before a new section of plate could be welded in. This springing left a tapering gap around 25% of the circumference



10 *Section through enlarged hearth and bosh, Queens Mary and Bess*



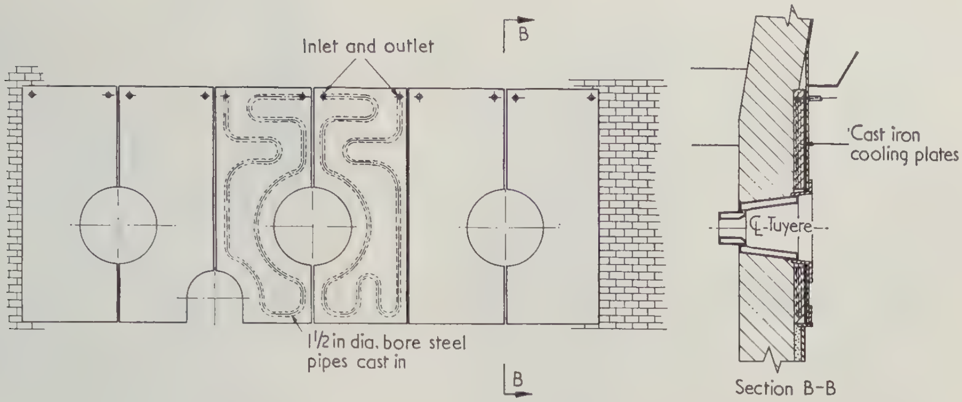
11 *Details of replaced stave coolers, Queen Anne furnace*

between the jacket and the refractories, so on completion of the welding repair numerous holes were drilled in the jacket and pressure grouting applied to fill this gap.

While the above operation was proceeding the two defective staves were located and dealt with in a novel manner. Having ascertained by probing that there had been no metal penetration, a flexible copper pipe was inserted in each of the leaking tubes and the space between the outer diameter of the flex and the inner diameter of the cooling stave tube grouted up by pouring in liquid 'iron cement'. By this we hoped to attain a metal-to-metal contact and so restore effective cooling, and were relieved to note that the furnace completed its campaign without further incident.

By now, with the previous troubles on Queen Mary and Queen Bess, followed by the trouble on Queen Anne and Queen Victoria, we considered that internal stave cooling of the hearth was not satisfactory to Appleby-Frodingham practice, so on relining these furnaces in 1958 the hearths were enlarged from 27 ft to 31 ft in the case of Queen Anne, and from 28 ft 6in to 31 ft in the case of Queen Victoria, dispensing with internal cooling staves in both cases and reverting to external spray cooling on the jacket, so far without further trouble.

We had no qualms about that decision, as by then we had six years experience in operating Queen Mary and Queen Bess without internal cooling staves, relying solely on externally spray cooling the hearth



12 *Gary design of tuyere-belt coolers*

jacket, which, even with only a carbon hearth wall behind the jacket, gave no cause for concern. The cooling was quite efficient, with no over-heating whatosever throughout the six years quoted.

Hearth enlargement had to some extent been catered for in the original design, and presented little difficulty in itself. But what was not allowed for at that stage was the reorientation of the hearth and bosh tuyeres, and this necessitated a new bustle-main, tuyere belt, and bosh, all of which were incorporated during the reline and hearth enlargement then in progress, Queen Victoria being off from 15 March to 4 May 1958, and Queen Anne from 22 November 1958 to 12 January 1959.

Tuyere-belt construction

In the day of the small furnace, i.e. up to 18 ft hearth dia., the orthodox method of construction in this area was of tucking the lower edge of the tuyere spectacle plates inside the top of the hearth jacket and securing the top edge by means of a circumferential steel band, the areas between being filled with exposed refractory brickwork incorporating a number of CI frames into which plate coolers were fitted.

The advent of the large furnace, coupled with higher blast pressure, called for a more robust construction of the tuyere belt, hence the jacket type, as shown in Fig.9, which still incorporated the plate coolers between the tuyeres.

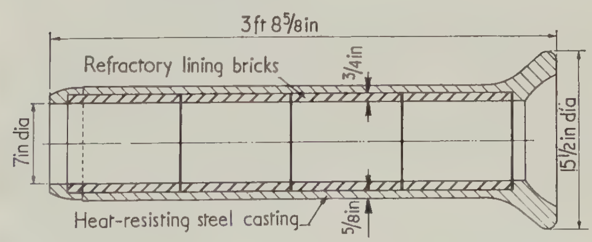
With enlarged hearth diameters and an increased number of tuyeres the internal face of the tuyere-belt brickwork was becoming so honeycombed with holes and thus inherently weak, that in 1954 it was decided to adopt the 'Gary' design of tuyere-belt cooler shown in Fig.12. This has now been fitted to all four furnaces, and not only does it contribute to a stronger internal refractory construction but it is cheaper to install and permits a completely gas-tight external construction. It also allows greater access facilities between the tuyere stocks, due to the elimination of the complicated mass of pipework required where numerous plate coolers are concerned, and thus presents a neat and tidy appearance around the furnace (*see* Fig.13).

While in the tuyere-belt zone it is perhaps opportune to say a little about another troublesome feature, blow-pipes, one which is receiving quite a lot of attention. High blast volumes combined with temperatures likely to exceed 1000°C demand refractory-lined steel blow-pipes, our current trend being toward the centri-diespun cast design (Fig.14) made in heat-resisting (stainless) steel. The refractory lining permits reasonably thin metal thickness together with a saving of about 10°C in blast temperature loss.

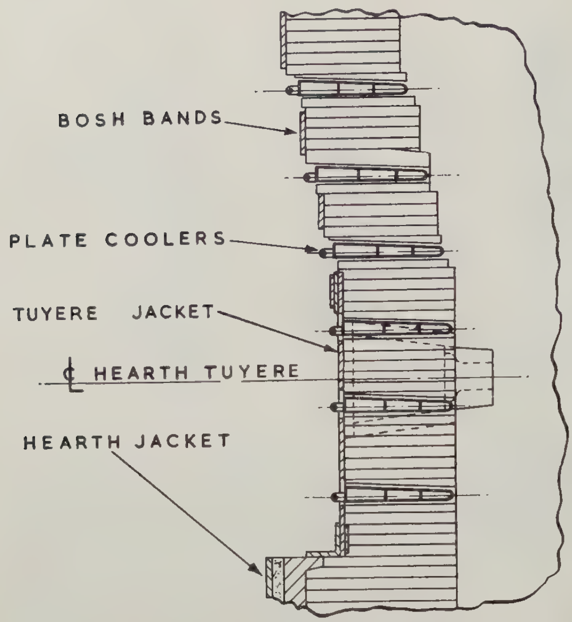
13 *Tuyere belt, Gary design*

Bosh-jacket construction

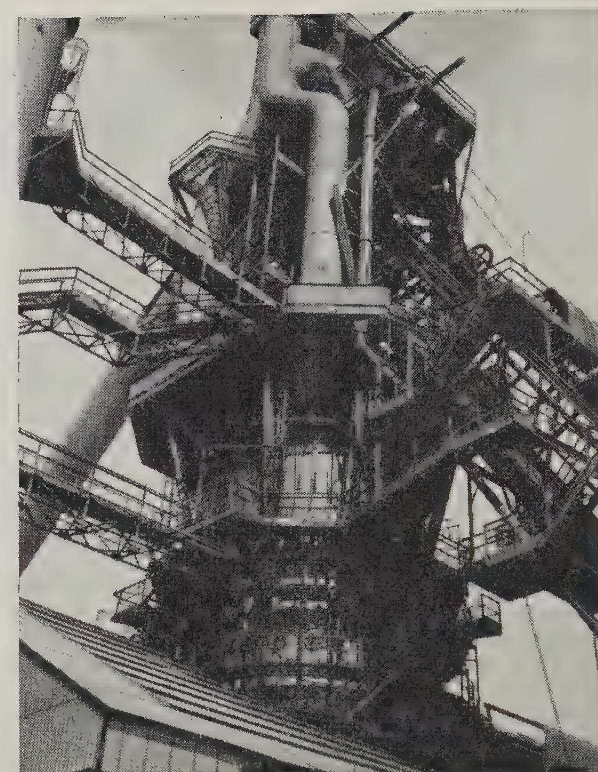
As this feature has already been covered to some extent in the section 'Hearth construction' it will be sufficient to say here that the 'banded' type of bosh construction shown in Fig.15 is no longer in use at Appleby-Frodingham, as it has been superseded by the spray-cooled type of jacket with a collecting trough just above the tuyere belt (Figs.9, 10). Like the hearth jacket, it is of all welded construction, generally in $1\frac{1}{4}$-in plate, with two circumferential spray rings, one immediately beneath the mantle and the other about mid-way between that and the collecting trough, each spray ring having a circumferential splash plate set $\frac{1}{8}$in off the jacket. The only troubles met with



14 *General arrangement of blowpipe*



15 *Banded type of bosh construction now no longer used at Appleby-Frodingham*



16 *Furnace stack stiffeners*

this construction have been where the top of the jacket is attached to the mantle, where welding defects have occasionally appeared, mainly in the region between the jacket and the mantle supporting columns, an area where access for sound welding is very difficult owing to lack of space. This trouble will be resolved during future relines by an improved method of fabrication which will permit all welding between the top of the bosh jacket and the furnace mantle to be done on the inner face of the connexion.

One other point worthy of mention here is that furnace cooling water for hearths, tuyeres, tuyere belt, bosh, or stack should always be softened, otherwise scale formation will undoubtedly arise allowing overheating to develop, and with the use of carbon refractories in the hearth, tuyere belt, and bosh, efficient cooling is of prime importance if trouble is to be avoided.

Stack construction

Here too, we have had considerable trouble, not in any way due to original structural design, but due solely to premature failure of stack linings.

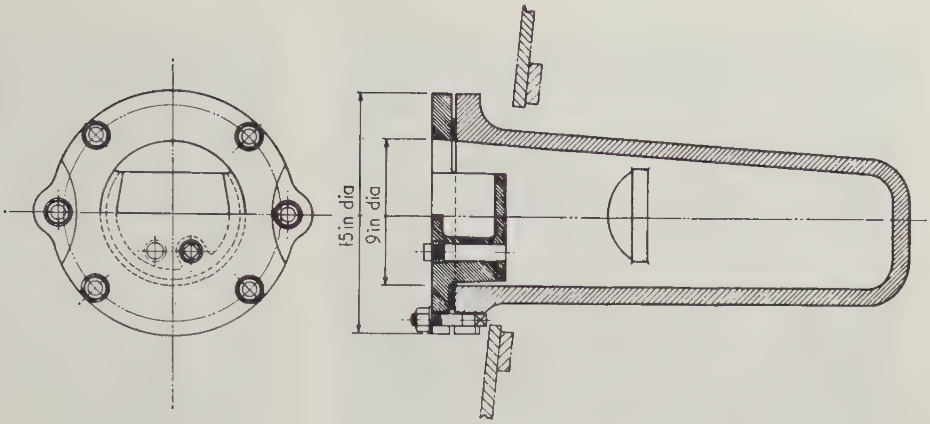
Both Queen Anne and Queen Victoria suffered a stack lining failure within two years on their initial campaign and had to be blown-out in turn for a stack reline only. Both failed together, the casing plates buckling from cone to mantle and resulting in the shearing-off of several top platform supporting brackets and both hoist-bridge supporting legs: the taper of the furnace casing allowed the latter to wedge themselves, thus preventing a catastrophe. Temporary measures were immediately taken while the furnaces were still operational to forestall impending disaster, final repairs being effected during the stack relines when the casings of both furnaces were more or less put in a straight-jacket by the provision of a series of prefabricated sectional vertical stiffeners welded to the casing from cone to mantle all around the circumference (Fig.16).

The 'first-aid' measures taken before this treatment consisted of welding massive supporting stools below each hoist-bridge leg to prevent further slipping, and re-attaching by welding the defective top platform brackets. Obviously there were all sorts of incidental issues also requiring close attention, e.g. at the outset of the trouble a number of register marks were made at various locations on the furnace tops and it is strange to relate that the movements observed on twice-daily checks indicated that variations were oscillating in both the vertical and horizontal planes, for reasons we could only attribute to furnace temperature conditions, although the distortion of the casing plates continued and extended on Queen Anne until it was blown-out on completing the stack reline on Queen Victoria.

It is a sad thought that while the scientist and the research worker put satellites into orbit around the world, the blast-furnace operator and engineer have had to tackle the troubles outlined here because a satisfactory stack lining for a hard-driven furnace on high sinter burdens had not as then been found. Some progress has since been made by using a high-alumina or a hard-fired china clay refractory in this region, with quite a measure of success, yet one must ask why should a furnace campaign be limited to, say, four years when apart from the life of a stack lining this figure could easily be doubled?

On their initial campaign Queens Anne and Victoria had three rows of stack coolers only, located immediately above the mantle, but during the stack relines referred to a further 13 rows were added, together with a spray cooling system, a practice now in use on all four furnaces.

The type of stack cooler in general use is that shown



17 *Stack cooler and cover*

in Fig.17, but we have since developed a new design which is now under trial on one furnace, and from its current performance in practice it may become our standard type (Fig.18). This design has the advantage of a rigid attachment to the furnace casing, gas-tightness, and as it is square in cross-section it is simpler to marry with the stack lining, and we believe, rightly or wrongly, that it also has a mechanical function by helping to some extent to hold the lining.

Now let us turn to 'throat armour', where in the old days on the Frodingham and North furnaces we had considerable trouble through carbon deposition on the steel armour, causing the crown brickwork to lift and thus disturbing the furnace top and displacing the bell and hopper gear.[1] The McKee type of throat armour shown in Fig.19 cured this trouble, but of course could not prevent its total collapse due to a refractory failure beneath, something we experienced when we began to drive the furnaces hard. Therefore this problem was tackled by supporting the throat armour on a continuous shelf ring attached to the inside of the furnace casing. This necessitated a completely new design of armour, and the type adopted, which is still in use today on all four furnaces, is shown in Fig.20. However, it is only right to record that our first venture with the shelf support principle failed owing to distortion in service, dislodging many of the throat armour castings. This inherent defect has now been solved by constructing the shelf ring in a series of sections, each of which support two throat armour castings. The only other change has been to substitute cast steel in place of hematite cast iron for the throat armour castings themselves.

Furnace top gear

Bells, hoppers, stock-rods, and bleeders

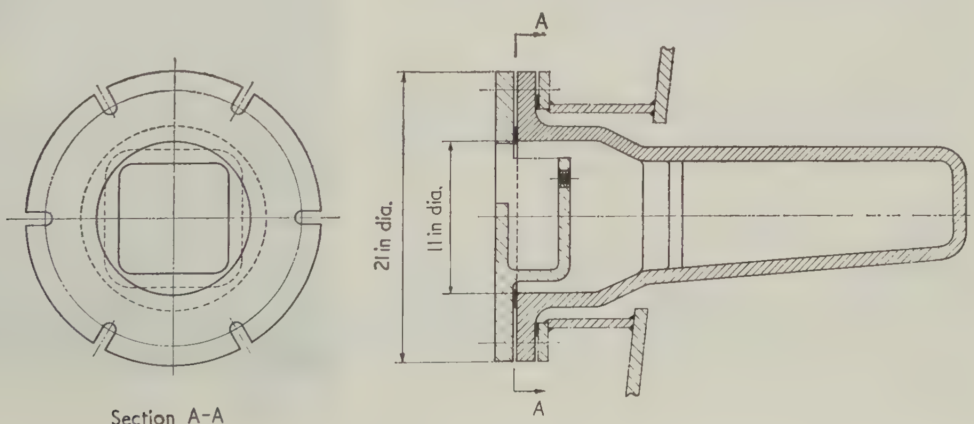
These items, known at Appleby-Frodingham as 'the big four', have also been the cause of many a headache. However, steady progress has been made to eliminate the troublesome factors in this group.

Large bell and hopper

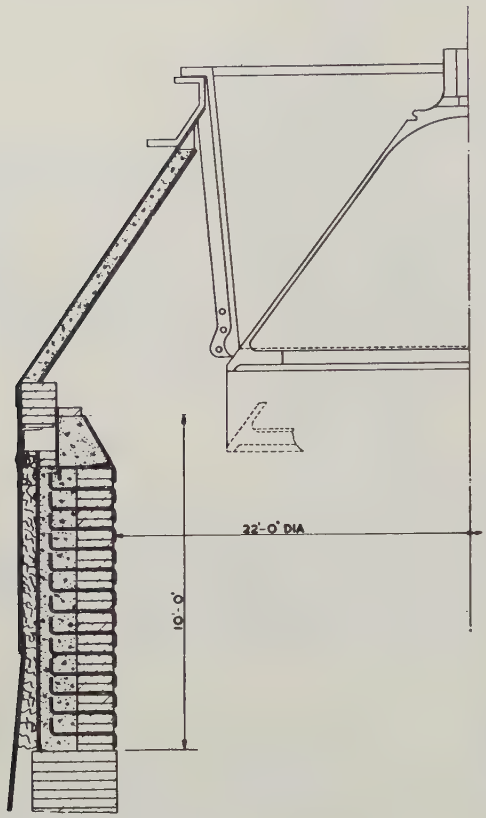
Originally on all four furnaces the large bell and hopper comprised a one-piece bell and a four-piece hopper, the reason for this being ease of dismantling and reassembly during reline periods, and before high sinter burdens this assembly was reasonably satisfactory in service when compared with the handling facilities it afforded when replacement was necessary. Hard driving, however, coupled with a more abrasive burden soon offset this advantage and during the past five years it became apparent that for this duty a one-piece hopper was called for, thus eliminating the trouble experienced with hopper joint distortion and its subsequent scouring action in these localities on both bell and hopper (*see* Figs.21 and 22).

It will be realized that the difficulties described resulted in flue dust depositions, gassy tops, and frequent ignitions, with attendant hazards to the furnace superstructure and bell and hoist operating ropes, thus making furnace top conditions intolerable.

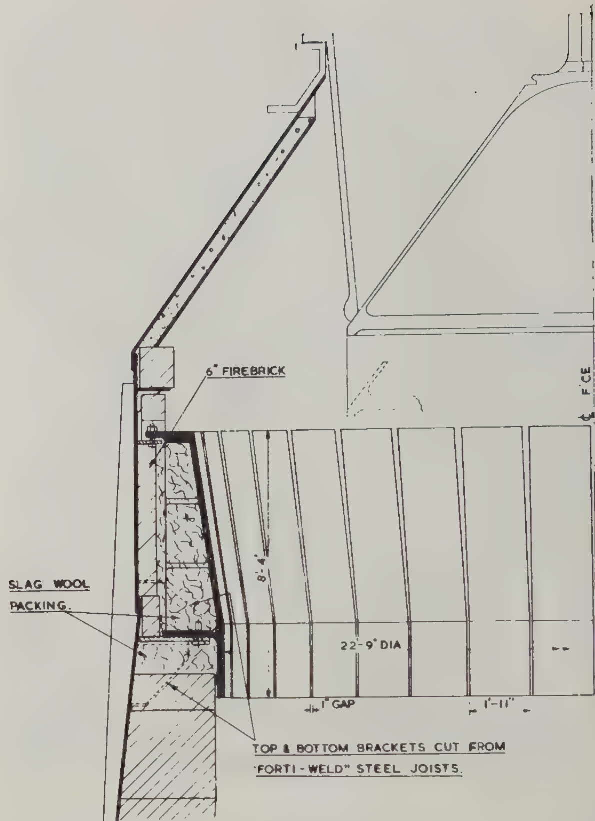
With regard to the life of the large bell and hopper, with appropriate renovation we can still achieve at least two furnace campaigns from each, and to improve further upon this, we are now trying out bells and hoppers hard-surfaced on the seating areas, a



18 *New type of stack cooler and cover*



19 *Old type of throat armour*



20 *New type of throat armour*

practice new to us now we are using a considerably more abrasive furnace burden.

Small bell and hopper
Once again, our main difficulties have arisen from abrasion, and to combat this we have not only increased metal thickness but have also carried out full-scale trials with these items made from alloy irons and steels, the current trend being toward increased metal thickness together with manufacture from alloy steels. For small bell-rod protection we are also trying alloy irons and steels and the results to date with each are quite encouraging.

Another troublesome item in this region has been the distributor gland seal, and our current practice here is to chromium-plate the moving surface of the gland ring, and to adopt a mechanical forced lubrication system, the latter feature now being in general use for the lubrication of all furnace top gear.

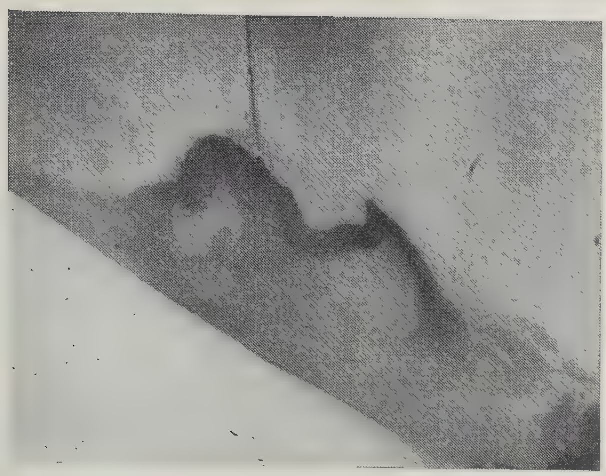
Stock-rods
It is probably true to say that a completely reliable method of measuring the furnace stockline has yet to be devised, and though current practice is by and large satisfactory, it is by no means foolproof, as false indications occur from time to time.

Fundamentally over the years stockline recording has remained based on a weighted ball or rod attached to a chain or wire rope. True auto-mechanization coupled with instrumentation to give charted records has been evolved, but the principle of physical probing to find the burden level still remains unaltered, and it is this particular aspect of the system which is prone to error.

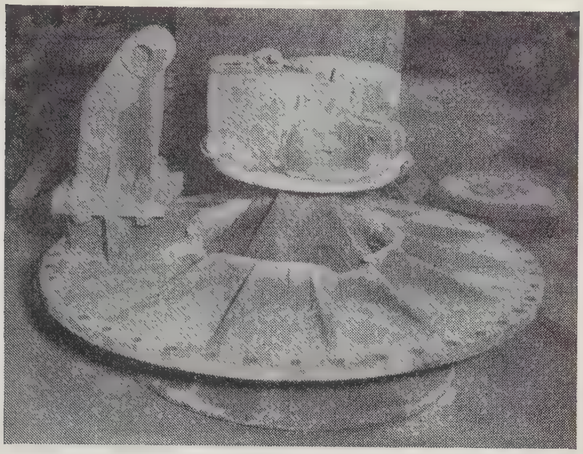
Scientific research devoted to this problem resulted in a full-scale trial on no.5 furnace at North Ironworks in 1950 with a BISRA 'pulsed sondar' system,[9] but this method failed owing to the interference of flue dust emissions in the top part of the furnace stack.

The next attempt at Appleby-Frodingham to resolve this problem scientifically took place in 1957 when a stockline level indicator devised by The United Steel Companies' Research and Development Department was installed on Queen Bess furnace, the principle involved being a radioactive source transmitting a range of signals to a reception panel located inside the furnace shell. This system showed promise until after a few months service we lost the radioactive

21 *Large-bell erosion*



22 *Large-hopper erosion*



24 *Furnace bleeder erosion*

source. A brief description of this equipment has been published.[10]

Currently we are using the orthodox method of auto-mechanical recording incorporating a weighted rod attached to the end of a locked-coil wire rope enclosed in a gas-tight tube on the furnace top, the final operation being by a flexible wire rope to the auto-electric winch located in the hoist-house (Fig.23).

Bleeders

In the author's early life these were known as torches, but whoever coined the name 'bleeders' certainly knew something, as the word is a suitable definition in more ways than one. We have had them literally 'blow-off', probably due to the pioneering spirit at Appleby-Frodingham. However, if our contemporaries have not yet experienced this they probably will do so in time. Once again it is the old trouble of abrasion, accelerated, no doubt, with the practice of 'checking' each furnace every 20 min, each check being followed by a 'slip', thus momentarily opening the bleeders.

Figure 24 indicates the problem we were up against, and to solve this, we have carried out many full-scale trials with hard surfacing and flame hardening techniques, best results to date being achieved by hard surfacing with tungsten carbide deposits on a cast steel base, applied over the whole of the wearing surfaces. By this method we have succeeded in extending the life of a bleeder from 10 weeks to 40 weeks, a figure we hope to improve upon.

This item would not be complete without a few words on the subject of bleeder changing, a hazardous job at the best of times owing to the limitations imposed by restricted space and height above ground level. Our current practice is to use a portable davit as shown in Fig.25; the orthodox runway beam system is not as yet considered reliable enough for our furnace practice where slips and bleeder ignitions are frequent occurrences.

Engineers consider that flue dust deposits combined with heat distortion and atmospheric effect could make a permanent rig unsafe to rely upon for handling weights at this height. Removal by helicopter has been considered and this may not be as silly as it sounds, considering the ever-increasing use that industry in general is making of such methods.

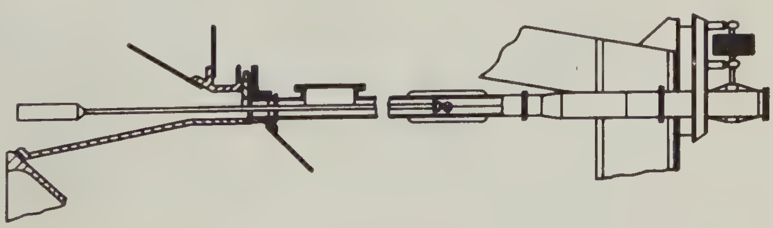
Gas offtakes, bleeder-tubes, and downcomers

Problems with the above have mainly been in the nature of localized lining failure, and to overcome this we adopted the monolithic type of refractory lining for these items.

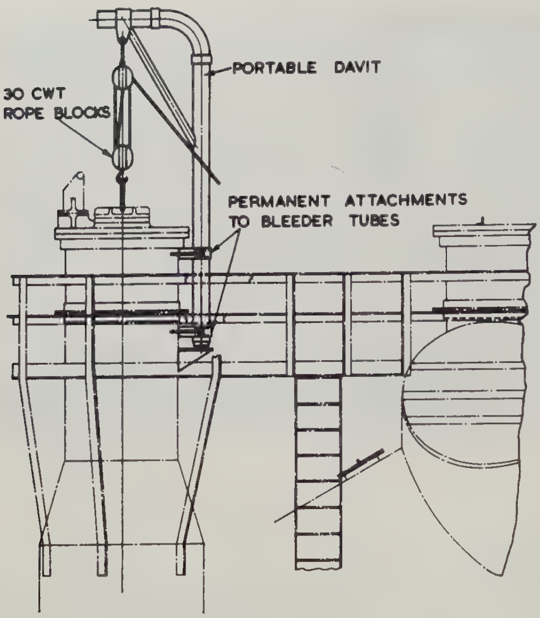
Our first application of this technique was in 1957 when it was substituted, with complete success, in place of brickwork for the lining of a bustle-main, and it has since become standard practice. Small projections are stud-welded to the inner surface of the steel shell, and castable refractories are then sprayed on by the cement-gun process.

When adopting this technique for the lining of gas offtakes etc., certain modifications are necessary, for in this case we are dealing with grit-laden gases as opposed to comparatively clean hot-blast in the case of the bustle-main, where although the temperature is much higher, the problem of abrasion is considerably less.

To combat abrasion it is advisable to reinforce the wearing surface with, say, 'Hexmetal' secured to the ends of the stud-welded projections. This means that the lining has to be dealt with in three stages, (*a*) the basic application of about $3\frac{1}{2}$in thickness, (*b*) the fixing of the reinforcement, followed by (*c*) the 1in thick final application integral and flush with the reinforcement mesh.



23 *Stockline test rod* (*By courtesy of Ashmore, Benson Pease and Co. Ltd*)



25 *Portable davit for bleeder repairs*

This technique has also been applied for the protection of furnace and dustcatcher top cones where in the past we have found it virtually impossible to retain refractory brickwork throughout a campaign. Alternative methods, such as castable application by the orthodox method of shuttering and pouring, have been tried with little success, and while it is yet too early to claim complete success for the cement-gun application in this sphere, results to date are promising.

IRON DISPOSAL

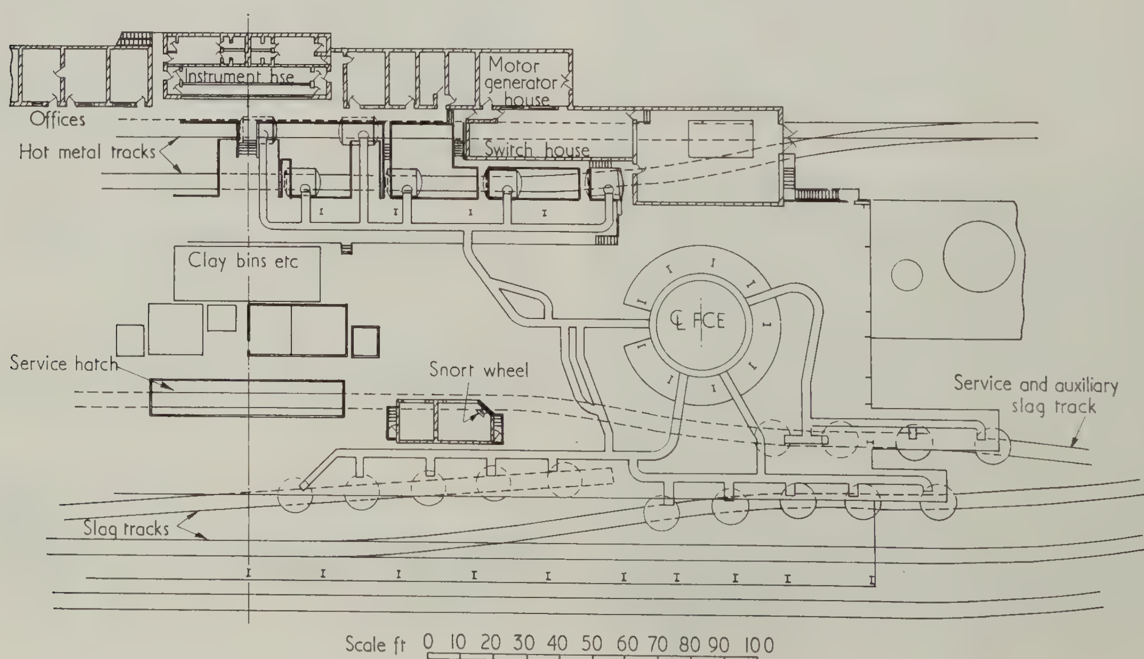
The economics of the company's steelmaking practice is based on the availability of hot metal. It is, therefore, of first importance that there should be a regular supply of molten iron from the ironworks to the melting shops with a minimum heat loss. To secure this, it is equally important to ensure the return of empty ladles to the blast-furnaces in time to suit a prearranged casting schedule. To meet these requirements a system of control exists within the melting shops organization, to direct the distribution of molten iron to the mixers and the pig casting plant, the latter comprising one two-strand unit (which since its installation in 1939 has poured about 5 million tons), plus two further strands commissioned in 1954 and 1957 respectively.

Figure 26 illustrates a typical Appleby-Frodingham cast house layout from which it will be noted that the disposal of iron and slag, is dealt with on opposite sides. This is a desirable feature when dealing with a furnace practice producing 26 cwt of slag/ton of iron, such segregation facilitating rail traffic movement by the avoidance of shunting delays that would otherwise undoubtedly occur.

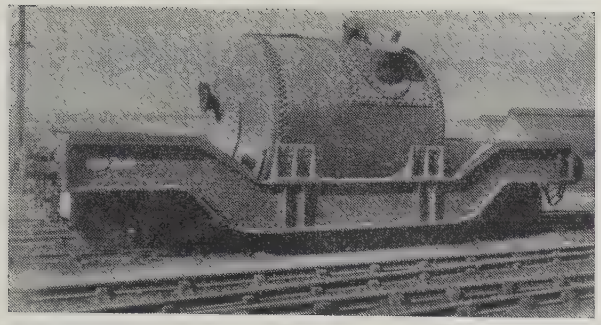
The total capacity of the hot metal ladle fleet should be sufficient to permit the withholding of a fair quantity of metal for a short time; on the other hand if it is too large the average track time is increased and skulls tend to form. For this reason it is the policy to operate with a safe minimum, and have spare ladles available for service when occasion demands. In the case of Appleby-Frodingham the number of ladles required for a given output usually follows a ratio of one per 1000 tons of weekly iron production, the total fleet today consisting of 34 complete assemblies plus six spare tanks (ladles).

Ladles are of the 'mixer' type (Fig.27) with a capacity of about 65 tons, and have a 9-in firebrick lining jointed with refractory cement. Breakouts are uncommon and on average the life of a lining is about 500 fillings.

Casing repairs are mainly confined to the fitting of



26 *Typical cast house layout*



27 *Hot-metal ladle and carriage*

pouring lips and hoods, but occasionally a casing is damaged by metal spillage during a fast cast. It has been proved that a larger hole is not the solution because under normal conditions splashes adhere to it and the hole quickly resumes its original dimensions.

Ladle carriages are of the 'crocodile' type mounted on interchangeable bogies fitted with roller bearings and mechanical lubrication. The bogies are overhauled at the central engineering workshops on a five-year cycle which amounts to about 13 per year.

Due to the heavy load involved (a full ladle and carriage weigh 120–130 tons) the three-link couplings are manufactured from $1\frac{5}{8}$-in 'Mangear' steel and as brakes are not fitted, two five-link safety chains are attached to each end of the carriage.

SLAG DISPOSAL

This in itself is a major operation, for in 1960 the four furnaces produced a total of 1 964 800 tons of slag, a weekly average of about 38 000 tons.

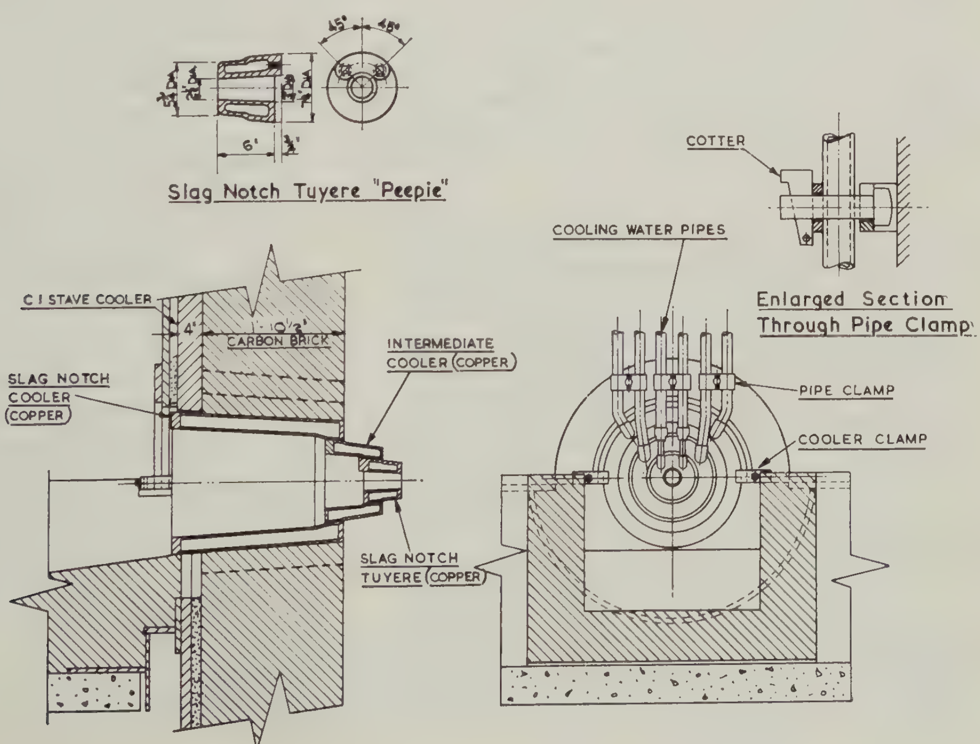
The method in use for dealing with this vast tonnage is as follows: each furnace is provided with three slag-notches, two operating, plus one auxiliary for emergency or intermittent use, and as previously stated final disposal to ladles is on the opposite side of the cast-house to the hot metal disposal (*see* Fig.26).

This method, unavoidable where large slag volumes are concerned, complicates the cast-house floor layout, adding difficulties to tuyere changing and good housekeeping, a further complication being the introduction of mechanical stoppers, emphasized by reference to Fig.28 which shows the slag-notch cooling water set-up.

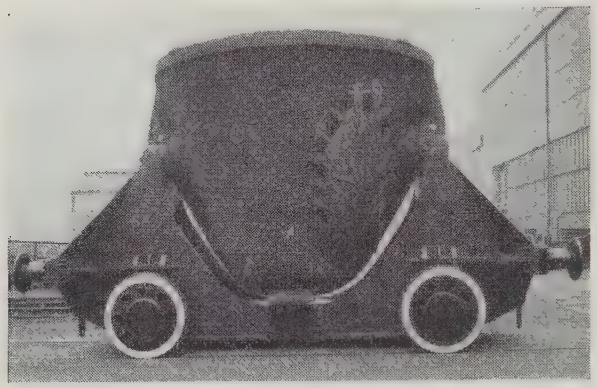
From the slag-fall outlets, removal in ladles has been continued because the tonnage involved could not be accommodated and cooled in pits within the space available near the furnaces, or even within a possible radius of flow. Ladles can be set in two independent groups of five at each furnace, with a further provision for four more ladles at each auxiliary slag-notch.

Currently we are using a slag-ladle fleet comprising 86 four-wheeled carriages carrying rope-tipped pans of $24\frac{1}{2}$ tons capacity (Fig.29), the tipping rope working on a large cast-iron segment allowing the tilting action to be sufficiently forceful to dislodge tight skulls. The pans are cast-iron and are of elongated shape, i.e. they have semi-circular top-ends with a flat taper-shaped gusset insert at each side between the ends, by means of which we have been able to increase the carrying capacity without undue sacrifice to orthodox shape and still keep the ladle top within the works rail gauge limit.

The final disposal of slag is by rail from each end of the blast-furnace site, the route to the south serving a molten slag granulation plant, or any of three tipping banks, while the route to the north takes the greater part of the total slag to seven pouring pits, each about 1000 ft long and 110 ft wide, from which the slag is subsequently excavated and transported in lorries of 15–25 tons capacity to slag crushing, grading, and processing plants associated with the works.



28 *Enlarged section and elevation at slag notch*



29 *Slag ladle and carriage*

The width of the pouring pit (110 ft) is an important feature, as it permits an unrestricted flow when pouring, thus improving the nature of the recoverable slag.

Finally with regard to slag disposal, mention must be made of a limited amount of 'cold-ball tipping,' but this is to a large extent dependent upon the demand for such, for coast and river bank erosion protection, etc., and also by the limitation of ladle standage for cooling, i.e. at least 24 h before tipping can take place.

Where do we go from here?

At the moment we are deeply involved in project 'Temper', a development approved by the Iron and Steel Board in June 1960 incorporating ironmaking, steelmaking, and rolling mill plant. Briefly this project provides for both iron and steelmaking capacities to be raised to about 2 million tons/year, the construction of a continuous casting plant for blooms, and for a billet and rod-bar mill.

With reference to the ironmaking section of this project, production-scale furnace trials have revealed that if the furnaces can be charged with a 100% graded sinter burden, then the existing blast-furnace plant has a capacity approaching 40000 tons/week[11] if provided with additional stove and gas-cleaning plant capacity. The ironmaking section, therefore, caters for the provision of:

(i) two additional pairs of continuous sintering machines ('E' and 'F' plants), complete with sinter coolers, return fines conditioning system, and improved sinter screening facilities at the furnace high line
(ii) three additional ore driers for Northants stone
(iii) a 'fine ore' bedding plant, adjacent to C, D, E, and F plants, i.e. at the extended Seraphim plant
(iv) four additional blast-furnace stoves, i.e. one per furnace
(v) an extension to the Apex and Seraphim gas-cleaning plants
(vi) additional steam-raising facilities, together with incidental ancillary plant and services.

When complete the combined sinter plant capacity will approach 150000 tons/week of which rather more than 110000 tons/week will be available to the blast-furnaces, the balance being undersized returns for re-sintering.

It is anticipated that this development will be completed by the end of 1962.

To forecast development beyond this stage would be unwise until operational results of project Temper have been fully assessed. By that time, other features such as oil injection, oxygen-enriched blast, and high top-pressure may appear more attractive to our practice than they do today.

There must be no relaxation in the search for better refractories and abrasion-resisting materials, even though they are more difficult and expensive to procure, as any such expenditure toward increasing the length of a furnace campaign and/or increased availability during a campaign is a sound investment. These remarks apply equally to the ore-preparation plants, where again abrasion problems are a common factor.

Over the years many attempts have been made to eliminate the orthodox blast-furnace by entirely different metallurgical processes; such methods may appear attractive in countries lacking coking coal and having an abundant hydro-electric power potential, but in the UK where large tonnage ironmaking together with reliability is required, the traditional blast-furnace is likely to remain predominant for very many years to come. In this direction it is significant to note that a preliminary design for a furnace allowing for a possible 40 ft hearth dia. has already received serious consideration at Appleby-Frodingham.

What of the future?

As this paper is more or less the author's swan-song, he feels he would be out of character if he were not 'awkward to the end', and with this in mind, he has decided to set down a few pointers to the future, namely:

(i) all future blast-furnaces for integrated plants in the UK should have a hearth diameter of not less than 30 ft, with provision for ultimate enlargement up to 35 ft
(ii) they should be designed for high top pressure, whether initially worked as such or not
(iii) they should be constructed with a 'free standing top', i.e. superstructure and charging gear etc. should be independently supported
(iv) they should be designed for a minimum of 40 lb/in^2 (gauge) blast pressure
(v) blowing capacity should be installed capable of supplying 160000 ft^3/min at 35 lb/in^2 (gauge) maximum continuous rating
(vi) hearth bottom pads should be of ceramic construction and that underneath cooling be forgotten
(vii) monolithic linings for HB mains and valve casings, bustle mains, uptakes, and downcomers should become standard practice, and a suitable monolithic lining for the stack should be pursued with vigour
(viii) all future stove shell bottoms should be hemispherical or dished in shape, and such design should incorporate provision for a central combustion chamber, with the stove bottom above ground level.

CONCLUSIONS

The author makes no apology for the simplicity of the paper, as the objective throughout has been to portray

progress, problems, and solutions relative to the development of the blast-furnace at Appleby-Frodingham. If this paper has done nothing more than to stimulate interest from an engineering point of view it will have served its purpose.

Of the years immediately before 1945 operators and engineers alike were to some extent frustrated, but once the fetters were freed they began to go places, and by 1961 they can rightly claim to have come a considerable distance.

It is sometimes thought that the rest of the ironmaking fraternity in the UK look upon Appleby-Frodingham types as 'beatniks'; perhaps we are, but when one considers the delinquent nature of the raw material we have to use, namely Frodingham ore 20%Fe–Northants ore 30%Fe, is there any wonder that 'we're nobbut queer'?

ACKNOWLEDGMENTS

The author wishes to express his thanks to the directors of the Appleby-Frodingham Steel Company for permission to publish this paper, and to colleagues for their assistance in its preparation.

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Fuel oil injection at Margam

K. C. Sharp, A.I.M., A.M.Inst.F.

SYNOPSIS

Oil injection trials at no.1 blast-furnace, Margam, are briefly described, together with operating results to date. The paper concludes that oil injection is both practical and safe, and includes details of the proposed final Margam installation.

At The Steel Company of Wales further expansion necessitated additional coking capacity to produce 2 500 tons of coke per week. Oil injection has offered a realistic means of avoiding this capital expenditure. 2017

INTRODUCTION

THE INJECTION of hydrocarbons has been under consideration at Margam for some time, and coke-oven gas, solid, and liquid fuels have been considered.[1] It is perhaps unfortunate that adequate supplies of coke-oven gas could not be spared, as this seems the only likely gaseous additive which can be made readily available to UK blast-furnaces. The use of solid fuels was considered but rejected on account of the additional plant necessary. The injection of liquid fuels presents little difficulty, and a relatively simple trial installation was installed at no.1 blast-furnace, the trials starting during April 1961.

ORIGINAL PLANT

No.1 furnace, the smallest unit and that on which the experiments were conducted, has a hearth dia. of 23 ft 9in and 14 tuyeres (Fig.1). The furnace was originally built in 1946 with a hearth dia. of 21 ft 6in and was the first large furnace in the immediately post-war Margam reconstruction period. The furnace has carbon in the hearth sidewalls, tuyere belt, and bosh, cooling being effected by heavy cast-iron staves inside the shell plating. The stoves and hot-blast mains associated with this unit were originally laid down in 1919 when the first blast-furnaces were built at Margam. There are four stoves, each having a heating surface area of 110 000 ft^2. The gas burning equipment is of similar age, and therefore the blast temperature is limited to a maximum of 750–800°C at normal air volumes. The stoves of the sister furnaces, nos.2 and 3, on the older plant at Margam are also of limited capacity, and partly to overcome this problem, a tonnage oxygen plant of large capacity, 550 tons/d at 90% purity, is under construction and will be available during October/November next. This will make possible a higher oxygen input into these furnaces at the same blast temperature. Recent improvements in stove refractories, together with a replacement of the older burners with modern high-capacity gas burning equipment, will enable higher blast temperatures at some future date. Meanwhile it was considered advisable to establish what could be achieved with the limited equipment available and with a very simple oil injection arrangement. The Margam blast-furnaces are normally 'free driving' with an operational technique to promote this condition. Blast temperature varies between 700–900°C and is used to control metal

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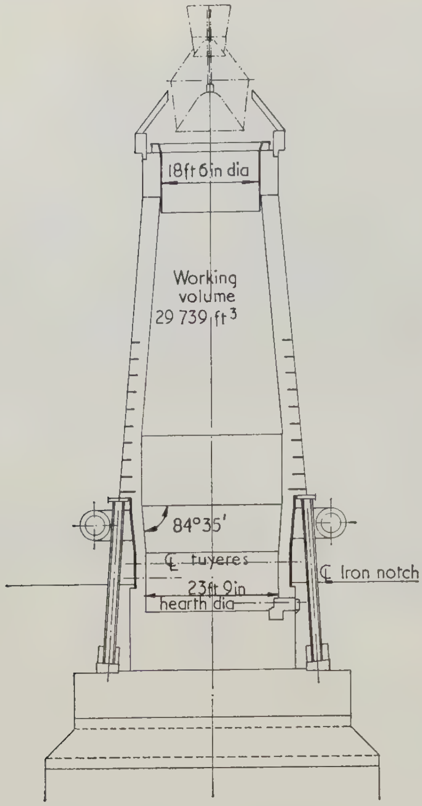
The author is with the Steel Division of The Steel Company of Wales, Port Talbot.

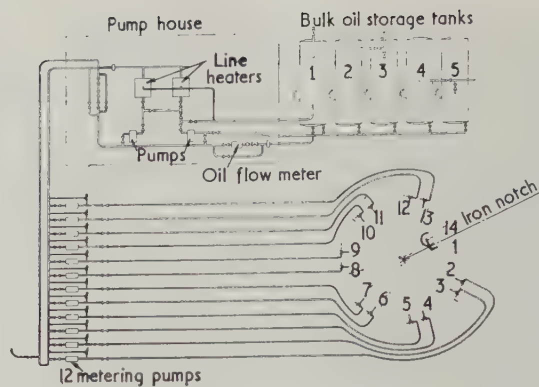


1 *Cross-section through no.1 blast-furnace*

quality. One objective of the trials was to determine the effect of injection on furnace operation, and particularly on the ore/coke ratio, blast temperature, stock movement, and blast pressure.

OIL INJECTION EQUIPMENT

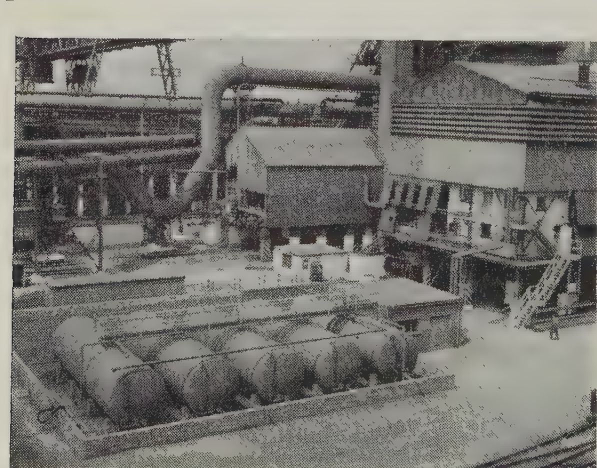
The area available for the storage of oil was not extensive, and the cost of oil storage had to be kept to a minimum. Sufficient storage was provided to cover three days continuous running at the likely maximum consumption, i.e. 1000 gal/h. The tanks were laid down in two stages. One 30 ft × 9 ft with a capacity of 12000 gal was to cover the first-stage trials (injection through one tuyere). When the first-stage trials were proven, four 30 ft × 9 ft tanks were then installed and



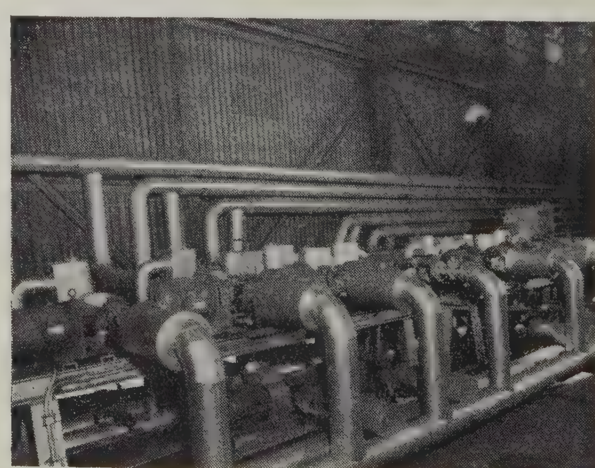
3 *Oil injection system for no.1 blast-furnace*

coupled by a common manifold. The total storage capacity therefore amounted to about 60000 gal (Fig.2). These relatively small tanks were used owing partly to site limitations and also to the advantage of early delivery.

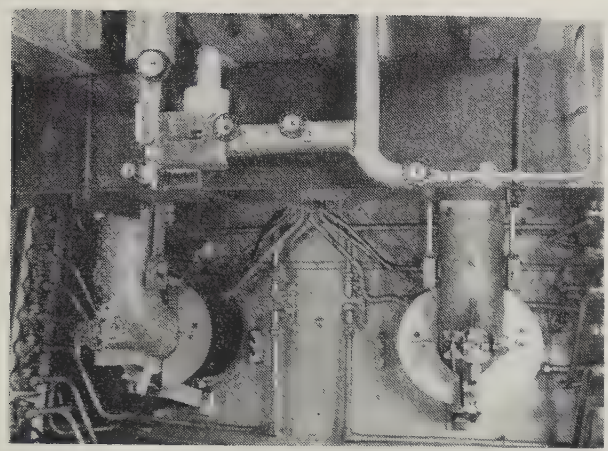
A pump house was erected adjacent to the tank farm with duplicate centrifugal pumps, each having a capacity of 1700 gal/h against a maximum pressure of 75 lb/in². Interconnected oil heaters with automatic temperature control and 20-mesh and 60-mesh dual filters ensure clean oil and minimize temperature differences. The oil pressure is kept constant by a pressure control valve situated in the return leg of the ring main, which is lagged and steam traced, permitting circulation of oil independently of furnace requirements. The installation (Fig.3) will handle roughly twice the estimated fuel requirements at the furnace with enough pressure to overcome the static head to the cast house and ensure a reasonable pressure (20 lb/in²) at the suction of the metering pumps which are situated on the roof of the amenity building (Fig.4). The metering pumps provide a variable volumetric flow to each tuyere and are rated at a maximum flow of 140 gal/h against a maximum operating pressure of 200 lb/in². One metering pump serves each tuyere, and this provides a very flexible arrangement. The 12 injection tuyeres are each fed independently by metering pumps, each of which has a graduated control situated on the pump body. The discharge lines from the metering pumps, which are arranged in pairs, are steam traced and lagged.



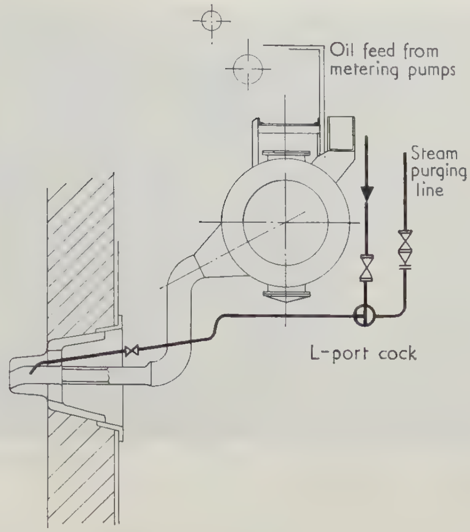
2 *Fuel oil farm*



4 *Metering pumps*



a



b

5 *Oil valve arrangement at tuyeres*

The arrangement at the furnace was deliberately designed to be simple but provision has been made for the future installation of automatic valves. At present an L-ported cock serves to admit oil to the tuyeres: there are three positions (*a*) 'Off', (*b*) 'Steam purge', and (*c*) 'Oil on' (Figs.5*a* and 5*b*). The steam purge ensures that oil may be speedily removed from the short length of pipe between the shut-off cock and the injector. A flexible connexion joins the pipe to the tuyere, and an additional shut-off valve is fitted at the tuyere; it is therefore possible to disconnect the flexible pipe. In the event of a partial blockage it has been possible to remove the obstruction by disconnecting the flexible pipe and allowing the hot-blast at furnace pressure to blow back through the tuyere injector.

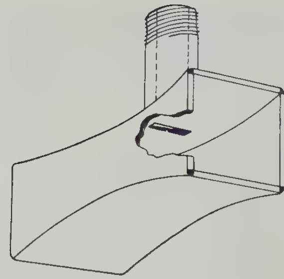
The oil flow to the furnace is checked against a flow recorder situated in the chart house on the cast house floor. Each tuyere is calibrated and set by shutting off and noting the fall in total oil flow. The desired tuyere rate may be achieved by adjusting the control setting on the metering pump and observing the increased flow shown on the recorder. Electrical on/off switches for individual metering pumps are located in the chart house, and emergency 'total oil off' switches are located at strategic points around the furnace. Initial proposals had included a ring main system with individual oil meters, indicators, and flow integrators for each tuyere, and oil to air proportioning. Most of this equipment was subject to extended delivery, and therefore it was decided to initiate the trials with a simple valve arrangement and manual control. Subsequent operations have shown that the installation need not be unduly complicated, but good instrumentation with adequate visual aids is desirable. The oil flow should be cut off automatically whenever blast pressure/volume falls below a preset level.

6 *Tuyere cooler, tuyere injection mock-up*

It was considered from the outset that the ideal arrangement for continuous blast-furnace operation would be injection through the sidewall of the tuyere. Reports had been received of injection via a lance down the centre of the blowpipe, but for practical operating considerations this method was rejected. Preliminary work soon proved that oil could be injected into the blast-furnace in the manner proposed, i.e. through a $\frac{3}{16}$in nozzle situated close to the nose of the tuyere. A mock-up was arranged on the cast house decking (Fig.6) which gave some indication of the jet size, positioning, and flow with varying nozzle sizes. It was soon noted, however, that when oil usings were increased above 300 gal/h (8·5 gal/ton of hot metal), combustion of the oil was not satisfactory. Difficulties were experienced at the gas-cleaning plant almost simultaneously with increased oil consumption to the level of 450 gal/h (13 gal/ton hm). A foam-like scum of fine ore and carbon particles formed on top of the water seals of the electrostatic precipitators (Fig.7). No operational difficulties were caused by this foam, apart from additional labour being necessary to wash away the foam.

Earlier discussions on the point of injection into the blast stream had indicated the advisability of having this as far back from the nose of the tuyere as possible, and tuyeres had been made with the injection point at varying distances from the tuyere nose. Tuyeres with injection nozzles 7in from the tuyere nose were installed in the furnace during the fourth week of the trials, and the injection rate stepped up to around 600 gal/h. The jets were still inclined towards the centre axis of the tuyere nose, and such repositioning soon indicated that a higher usage of oil was possible. The earlier difficulties at the gas-cleaning plant largely disappeared when the modified tuyeres with injection point 7in from the tuyere nose were fitted. A dark,

7 *Carbon foam at gas cleaning plant*



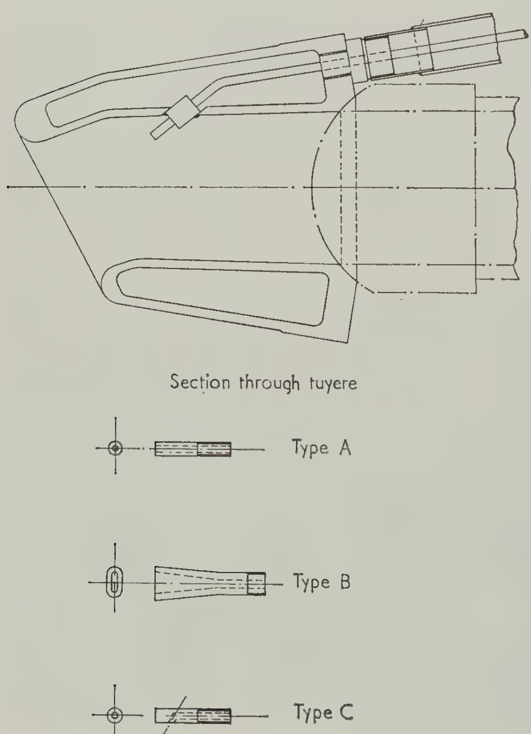
9 *Venturi injection nozzle*

thin, oily film still persisted on top of the water seals, but the foaming troubles had disappeared.

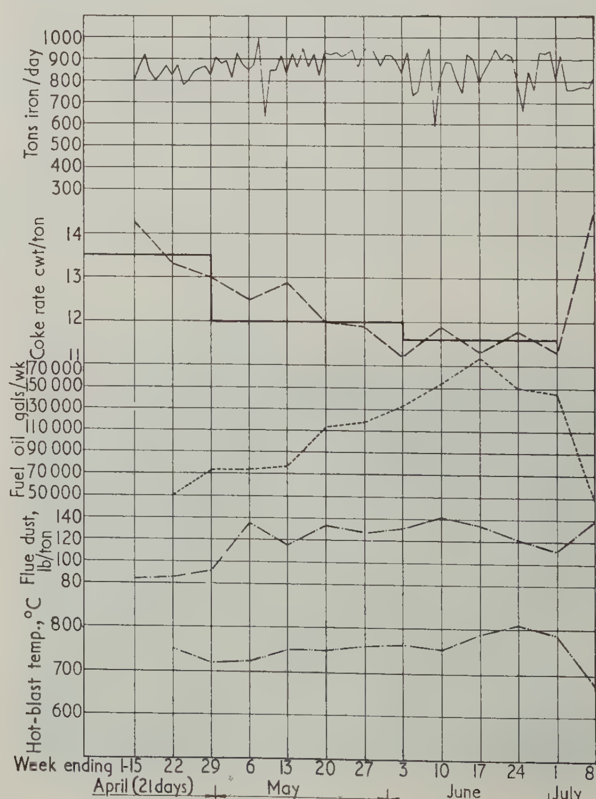
Further thoughts on jet design resulted in re-positioning the jet again, and a redesign to effect improved combustion of the oil. Atomization had been considered before the trials started, but had been rejected on the grounds that the installation should be as simple as possible. It was considered that with oil fed into a blast stream of 800°C with perhaps increased oxygen content, combustion would be instantaneous. Details of the tuyere and nozzles, which have proved satisfactory, are shown in Fig.8. Stainless steel injector nozzles of $\frac{3}{16}$in bore and of various design are screwed into a copper tube brazed into the tuyere body. The nozzle projects 3in into and at varying angles to the blast stream. The oil injection pressure varies between 30 and 100 lb/in^2 at an oil temperature of 180°F. The viscosity of the oil at this temperature being 200 s Redwood no.1. Experiments are proceeding with a venturi-shaped nozzle, details of which are shown in Fig.9.

RESULTS OBTAINED

The results to date have been very encouraging, with a steadily decreasing coke rate as the quantity of oil was increased. The flue-dust loss increased somewhat when oil usings were increased to 600 gal/h (17 gal/ton hm), although the slight increase at the higher output rate is not unduly excessive. The Margam blast-furnaces are operated to a stringent iron quality, and results over many years have shown that iron of very low Si and S can be produced with complete safety.[2] No.1 furnace normally produces high-P iron (1·8–2·0%P), to a specification of: Si 0·3–0·5%, S below 0·030%, and Mn 0·5–0·6%. This iron quality is necessary as the steel converter practice necessitates low Si and Mn on account of excess ejection if these limits are exceeded. The blast-furnaces producing such iron have to be



8 *Detail of tuyere and nozzle design*



10 *Graph of performance data*

TABLE I Fuel oil injection trials on no.1 blast-furnace

	First period: 21 days Base period: 25 March–15 April 1961	Second period: 35 days					Third period: 28 days				Fourth period: 7 days
		7 days 6 May	7 days 13 May	7 days 20 May	7 days 27 May	7 days 3 June	7 days 10 June	7 days 17 June	7 days 24 June	7 days 1 July	7 days 8 July
*Iron production**											
Ton hm/d	818	875	876	895	919	902	828	852	888	840	794
Ton hm/d/ft² hearth area	1·846	1·975	1·977	2·020	2·074	2·036	1·869	1·923	2·004	1·896	1·792
Net rates											
Coke, cwt/ton hm	14·37	12·45	12·73	11·96	11·93	11·21	11·85	11·28	11·79	11·33	14·47
Oil, lb/ton hm	...	119·17	132·23	174·13	182·66	211·91	282·18	286·04	229·61	241·85	...
Flue dust, lb/ton hm	85·16	135·97	116·36	134·21	129·22	132·25	141·37	134·88	121·87	111·88	140·67
Slag volume, cwt/ton hm	8·59	7·61	7·45	7·40	7·75	7·20	7·92	7·32	7·66	7·78	7·39
Burden, %											
Swedish ore	28·7	36·6	33·7	33·0	32·7	34·9	30·9	32·5	32·3	31·5	27·6
Soft ore	8·1	5·6	8·2	9·1	6·8	8·8	5·4	5·4	8·3	5·3	22·8
Sinter	48·9	50·3	50·8	49·5	49·1	47·9	50·9	52·0	48·5	53·5	41·6
Home ore	5·9	...	0·2	...	...	...	...	...	...	...	3·7
Fe	53·4	55·65	56·14	55·60	55·35	56·30	55·25	56·96	55·32	54·87	56·02
Fluxes											
Basic slag, cwt/ton hm	1·15	1·29	1·12	1·84	2·43	1·23	2·95	2·23	2·18	1·96	0·75
Limestone/Magstone, cwt/ton hm	2·56	2·67	2·61	2·35	2·15	1·95	2·25	2·03	2·24	2·22	2·90
Slag basicity											
($CaO+MgO/SiO_2+Al_2O_3$)	1·02	1·05	1·07	1·05	1·07	1·03	1·11	1·06	1·05	1·06	1·02
Air blast											
Volume, ft³/min (metered)	48520	50400	50590	49360	50620	50310	50350	50120	49340	49400	45690
Volume, ft³/min (in² tuyere area)	110·62	114·89	115·33	112·52	115·39	114·69	114·78	114·26	112·48	112·61	104·16
Volume, ft³/min/lb (coke)	53·23	59·45	58·25	59·27	59·34	63·99	65·99	67·07	60·61	66·74	51·15
Temperature, °C	713	727	749	754	760	766	760	793	810	788	677
Moisture, gr/ft³	3·65	4·13	3·45	3·65	3·22	3·30	4·04	4·50	4·38	4·81	4·49
Pressure, lb/in²	14·16	14·8	14·2	15·2	15·0	15·2	15·6	16·1	15·8	15·3	13·7
Top gas											
Temperature, °C	238	266	260	238	238	277	316	299	277	310	210
Analysis, % CO	31·00	29·80	29·88	28·63	28·72	28·70	30·24	29·80	29·27	29·77	29·73
CO_2	10·44	10·43	10·20	11·23	10·82	10·73	8·80	9·83	11·13	10·07	11·63
H_2	1·54	3·20	3·40	3·46	3·70	4·18	4·32	4·30	3·82	3·93	1·83
Ratio CO/CO_2	2·97	2·86	2·93	2·56	2·63	2·68	3·43	3·04	2·63	2·97	2·64
Analyses											
Iron, % Si	0·44	0·47	0·46	0·39	0·45	0·46	0·50	0·40	0·37	0·50	0·52
S	0·026	0·025	0·025	0·024	0·023	0·029	0·022	0·029	0·033	0·023	0·023
P	1·96	2·06	1·96	2·01	2·04	2·15	2·03	1·92	1·89	1·73	1·78
Mn	0·64	0·62	0·63	0·72	0·70	0·68	0·68	0·70	0·66	0·72	0·74
Coke (dry), % Ash	10·70	10·50	10·50	11·00	10·70	10·90	10·50	10·80	11·20	10·10	10·40
S	0·88	0·94	0·98	0·90	0·96	0·82	0·79	0·97	0·87	0·91	0·85
Oil, % C	...	86·00	86·00	86·00	86·00	86·00	86·00	86·00	86·00	86·00	...
H_2	...	13·00	13·00	13·00	13·00	13·00	13·00	13·00	12·00	12·00	...
S	...	1·00	1·00	1·00	1·00	1·00	1·00	1·00	2·00	2·00	...
Tuyeres lost	1	...	...	1	...	...	...	...	1	1	2
Tonnage on lining (3rd campaign)	494465	512201	517803	524045	530407	536623	541899	547861	554037	559823	565237
Burden ratio lb ore/lb coke	2·52	2·78	2·66	2·90	2·92	3·06	2·95	3·08	2·97	3·11	2·39
Coke base, lb (av.)	14800	14717	13890	13220	13220	13220	12432	12432	12800	13200	14800
Charges/d	86	83	83	90	91	84	79	87	91	81	84
Downtime, min	3–58	0–26	12–21	0–42	1–55	2–31	15–03	...	1–04	2–37	4–18

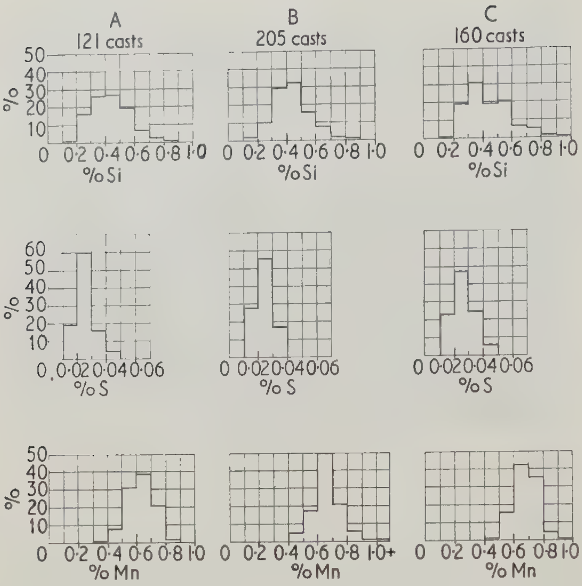
* Tons hm/d Tons hot metal per day

operated under very close control and at a slightly higher coke rate than could be achieved under less stringent quality specification. Nevertheless the furnace normally operates at around 14 cwt net coke/ton and the base period of three weeks just before the trials and with a similar burden averaged 14·30 cwt/ton.

The progressive reduction in coke rate is shown in Fig.10 and Table I, with associated operating data. Comparing the nine-week period May and June with the adjusted base period figure (higher slag volume and lower blast temperature), the average coke savings of 250 lb/ton were achieved by the injection of 206 lb of fuel oil/ton of hot metal, the replacement ratio lb oil/lb 84%C, 4·5%H_2O coke being 0·81.

A recent paper by Bell and Taylor[3] details a method of forecasting the results of fuel injection, and although the work only came to hand after the two monthly test periods, the method has been applied. The Margam results appear to be more favourable than those forecast in this paper, with an oil carbon equivalent of around 0·87 to 1 of coke carbon. Bell and Taylor consider this problem from the viewpoint of constant direct reduction or their constant, $FeO_{(D)}$. Any reduction achieved by hydrogen in the rising gases would affect this constant and may well be the reason for these different findings.

As no.1 furnace is the smaller unit it is often used for either basic or high-P iron, and for a few months before the trials had been on basic grade. However, the iron made during the trials was of high-P quality for the VLN plant, and histogram *A* (Fig.11) shows typical Si, S, and Mn levels for a few weeks before the trials with the P fairly steady between 1·80 and 2·00%.



A Base period 1–15 April (21 days)
B First period with oil: five weeks ended 3 June (35 days)
C Second period with oil: four weeks ended 1 July (28 days)

11 *Histograms of iron quality*

Histogram *B* shows iron quality produced when using 1·0%S oil, and histogram *C* when using 2·0%S fuel oil. Using oil up to 2%S no difficulties were experienced in maintaining the low-S specification, even though such use increased the total S load by about 18% compared with normal operation.

During the early stages the principle objective was to establish to what extent solid carbon could be replaced by liquid oil, and increased output was not deliberately sought. Nevertheless, output has increased by some 10% which is considered due to increased thermal efficiency. At the start of the trials no.1 blast-furnace was already operating at high efficiency and close to the optimum within the limits of the burden and existing equipment. For several months the furnace had regularly produced 800 tons/d and it will be noted that with optimum injection the output was raised to around 900 tons/d. It is not considered that further output is possible without increased oxygenation of the air blast or the ability to blow more wind at the same or higher blast temperature. The blast volume had to be held, owing to limitations, at a constant level of 50000 ft^3/min and throughout the trials the furnace operation has been very satisfactory although with coke rates below 12·0 cwt/ton there were indications that the increasing ore/coke ratio had a 'stiffening' effect. At 850 gal/h injection rate (25 gal/ton hm), this effect did not prohibit free driving, and resulted in coke rates of 11·25–11·70 cwt/ton. With oil usings at 1000 gal/h (28 gal/ton hm) the blast pressure increased by about 2 lb/in^2 with a definite worsening in stock descent. Occasionally there were clear indications on random tuyeres that the furnace was not accepting all of this additional oil which burnt back in the blowpipe and tuyere sights. Nevertheless the performance further improved and for five consecutive days the coke rate was steady at 10·80 cwt/ton. Unfortunately a quantity of stock coke (15–20%) had to be used on all furnaces, and the ore/coke ratio had to be adjusted accordingly. Simultaneously the period of

TABLE II Thermal balances on no.1 blast-furnace

	Base period: without oil 21 days 26 March–15 April 1961		Second period: with oil 35 days 5 weeks ended 3 June 1961		Third period: with oil 28 days 4 weeks ended 1 July 1961	
Heat required, Btu/lb pig iron						
Reduction of oxides	2536		2557		2537	
Heat content of pig iron	765		775		759	
Heat content of slag	334		295		305	
Calcination of carbonates	63		58		54	
Radiation and cooling	193		177		186	
Evaporation of moisture	46		43		43	
Total	3937 (100%)		3905 (100%)		3884 (100%)	
Heat supplied						
Combustion of carbon to CO_2 (coke)	7658		6376		6072	
(oil)	...		848		1333	
Heat carried in blast	764		776		839	
Hydrogen addition (H_2–H_2O)	8	8430	187	8187	341	8585
Less sensible heat in top gas	359		398		418	
CO in top gas	4216	4575	4015	4413	4349	4767
Total	3855(97·9%)		3774(96·7%)		3818(98·3%)	

steady burdening ended as no.3 furnace, which had been off for relining, was recommissioned.

The reduction in coke rate is encouraging, and clearly if higher blast temperatures were practical on this unit, then the coke rate would be even lower. Thermal balances have been calculated for the trial weeks; these are shown in Table II and a reasonable balance is evident.

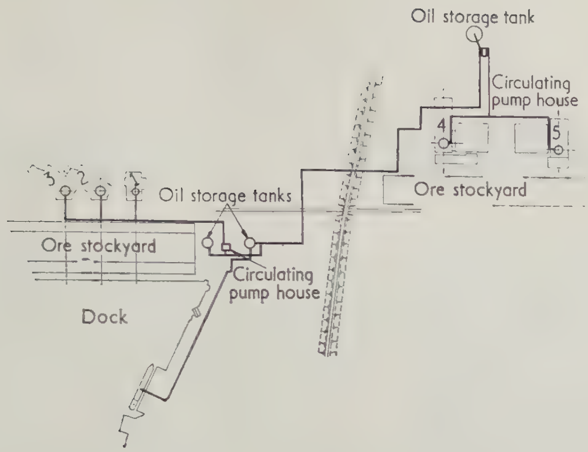
Throughout the trials the stock descent has been extremely smooth, and only during the latter stages with oil usings around 1000 gal/h was any 'stiffening' effect noted. This was to be expected and may be taken as an indication of the maximum quantity of oil which could be satisfactorily injected into this particular furnace.

It is considered that the ultimate coke rate with oil, oxygen enrichment, and really high blast temperatures will be governed primarily by the ore/coke ratio that individual furnaces will accept, which in turn depends on the practice, with particular regard to physical and chemical degree of burden preparation. Coke rates of 10 cwt/ton should be possible on most modern furnaces burdened with rich ores and sinter, and lower coke rates are likely on modern high-capacity units, when carefully sized pellets/briquettes and screened fluxed sinter form the burden. Before changing the P specification during the week ending 8 July, it was decided to take all oil off the furnace. There was a very sharp rise in the coke rate; the results obtained are shown in the last column of Table I. When the change to basic iron was complete, oil injection was resumed and the reduction in coke rate, which had been previously observed, was obtained again.

It had been hoped to hold short trials with increased oxygenation of the air blast, although these had to be deferred owing to the shortage of tonnage oxygen.

OPERATION

No change in furnace operational control measures was necessary, and tuyere conditions remained normal. Very occasionally it was necessary to stop temporarily oil injection on individual tuyeres to correct local



12 *Layout of proposed fuel oil injection system*

abnormalities in tuyere appearance. If additional blast temperature had been possible, these minor troubles could have been corrected without interfering with the oil injection rate.

Changes in combustion conditions of the oil could be expected to add further variables to furnace operation. This was realized but it was found in practice that within the range of oil used, changes did not seriously affect operations or performance. However, it is felt that at high oil usings/ton of iron this new change in the blast-furnace process would assume greater significance, and it would be of value to have some fundamental research done on this aspect of fuel injection. More information is required on the products of combustion or conversion of oil in the tuyere zone. The design of a simple practical burner which will give as near as possible constant products of combustion with variable oil and blast rates, is also urgent. Both aspects are currently being examined by our research and operating staffs.

FUTURE DEVELOPMENTS

Mention has already been made of the 550 tons/d tonnage oxygen plant in construction, and this capacity might well be increased if it is shown that the larger furnaces can benefit in a similar manner with simultaneous oil and oxygen injection. A scheme is being prepared to allow for fuel oil injection at the five Margam blast-furnaces; details of the layout are shown in Fig.12.

The oil to be used will be heavy fuel oil of 1–2%S content having a viscosity of 2000 s at 100°F and a specific gravity of 0·97. This oil will be imported by sea in tankers of 500–750 tons capacity and off-loaded at a nearby wharf. Alternative emergency arrangements for road delivery will also be provided. The tankers will discharge the oil direct to a transfer tank of 500000 gal capacity situated on the south end of the stockyard. From the transfer tank the oil will then be pumped to each of two service tanks also of 500000 gal capacity; one tank to be sited adjacent to nos.1, 2, and 3 furnaces and the other sited near nos.4 and 5 furnaces. The total tank capacity will provide sufficient oil to permit production at normal output levels on all furnaces for about 6 days. This will be sufficient capacity to cover delays in tanker turn-round due to climatic conditions. Oil will be pumped to and from all tanks by positive displacement pumps, and therefore ring mains will be provided for each furnace with pressure relief by-passes.

CONCLUSIONS

1. The trials at no.1 blast-furnace have shown that oil can be injected into the tuyere zone of a blast-furnace without undue difficulty, 25–28 gal/ton of iron being standard practice.
2. Up to 2 cwt/ton of coke can be replaced by such injection without appreciably increasing the operating blast temperature. Where this may be increased by, e.g. 150–200°C, then at least another 1 cwt (making 3 cwt in all) ought to be replaced and possibly more.
3. A slight gain in output may be expected (10%) without measurably increasing either the oxygen content of the air blast or the wind rate. Although this is not yet proved, it is possible that increased oxygenation of the air blast may well result in a further significant gain in production.
4. The iron quality was maintained even when using fuel oil of up to 2·0%S.
5. The capital cost of the equipment used was £30000, and the results to date have indicated a saving of 5*s*. 0*d*.–7*s*. 6*d*. per ton of iron.

ACKNOWLEDGMENTS

The author gratefully acknowledges the co-operation of Shell-Mex and BP Ltd. He is indebted to engineering and operating management of the blast-furnace department, without whose continued interest and support these trials could not have been undertaken. Appreciation is also recorded to the directors of The Steel Company of Wales for permission to publish this paper.

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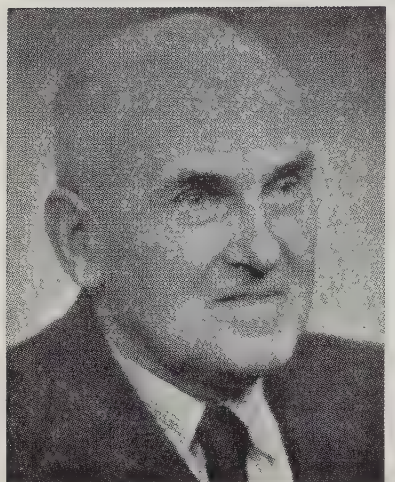
Dr H. R. Schubert



Dr H. R. Schubert, Historical Investigator to The Iron and Steel Institute, died on 9 July. He was born in 1884 at Milisch, in Silesia, the son of a Lutheran clergyman of Swiss ancestry. He studied history, economics, and philosophy at various continental universities from 1903 to 1907, obtaining the degrees of M.A. *and* PH.D. *He was Assistant at a seminary of the University of Marburg for two years.*

In 1909 Dr Schubert passed the examination enabling him to enter the Berlin Archive Service, and by 1931 he had risen to the rank of State Archive Director at Wiesbaden. He was deprived of this post in 1933 because of his resistance to Nazism. He then lived for some time in Italy and later settled in England with his English wife, subsequently acquiring British nationality.

From 1940 to 1947 Dr Schubert lectured at the University of Reading. At the end of 1947 he was appointed Historical Investigator to The Iron and Steel Institute, a position which he held until he retired in 1958. He joined the Newcomen Society in 1948.

In 1952 the American Iron and Steel Institute suggested, and the Institute readily agreed, that he should visit the USA in order to consult with the organizers on the restoration of the first ironworks project at Saugus, Massachusetts.

While still living in Germany, Dr Schubert had achieved an established position as a learned and careful scholar. He had contributed important chapters to Johannsen's 'Geschichte des Eisens' and written the first part of the magnificent 'Vom Ursprung und Werden der Buderus'schen Eisenwerke Wetzlar'. His work in England enhanced his reputation. He showed an astonishing skill in discovering, in private and public collections, important documents which referred to the iron and steel industries of the country. Always primarily a medievalist, his interests widened to embrace the whole period of 2 000 years which has passed since iron was first used. He successfully surmounted two difficulties. Although he had no practical or scientific knowledge of ironworking he acquired a sound understanding of modern processes so that never in his writings did he make those little errors of terminology which so often betray the amateur and irritate the practical steelmaker and he had a profound understanding of how primitive processes and plant actually worked. Also he surmounted the handicap of writing in what had originally been to him a foreign language. Sometimes, indeed, his style in English was a little stilted and in his major work the desire to omit no scrap of evidence tended occasionally to make his writing a little drawn out, but the facility with which he wrote in English would have been creditable if this had been his mother tongue.

Even before his appointment as Historical Investigator, Dr Schubert had been engaged in compiling a history of the British iron and steel industry. His appointment enabled him to devote most of his time to this work and in 1957 there was published his 'History of the British Iron and Steel Industry from c.*450 B.C. to A.D. 1775'. In addition Dr Schubert wrote many shorter articles and he contributed important chapters to 'A history of technology' (published in 1958), but he was probably best known to members of the Institute as the author of the many learned and delightful historical notes which he contributed to the* Journal.

W. D. Johnson

William Danily Johnson, one of the oldest Life Members of The Iron and Steel Institute, died at Buglawton, Congleton, on 12 June, aged 87.

Mr Johnson trained as a pharmaceutical chemist in London before becoming interested in metallurgical chemistry. He worked for a time in the laboratories of the Brymbo Iron Works in North Wales, then joined the firm of Gilbertsons at Pontardawe, South Wales. As manager of the Bynea Steel Works Mr Johnson was largely responsible for the erection of the works just before 1914. During the first world war he held a post with the Ministry of Munitions in Middlesbrough. In 1920 he retired from the industry and took up farming.

Programme of the Autumn General Meeting 1961

The Autumn General Meeting of The Iron and Steel Institute will be held in London on **Wednesday** *and* **Thursday, 29** *and* **30 November 1961.** *It will be followed by the 43rd Meeting of the Iron and Steel Engineers Group on* **Friday, 1 December 1961.** *Sessions will be held at the Federation of British Industries, Tothill Street, London SW1, and at the offices of the Institute, 4 Grosvenor Gardens, London SW1.*

The technical sessions will comprise a symposium on 'The future of ironmaking in the blast-furnace' and short sessions on the thermodynamics of slags, oxidation and scale bainite, and high-alloy steels. The meeting of the Engineers Group will be devoted to the discussion of a paper on the energy balance of an integrated iron- and steelworks. The symposium and the Engineers Group Meeting will be held at the Federation of British Industries and the other sessions at the offices of the Institute. The programme of the meeting is given below.

Some of the papers for the symposium will be published in the Journal *in advance of the meeting, and the remainder will be available in preprint form to those registering for the meeting. The paper for the Engineers Group meeting will be preprinted and will appear, in due course, together with a report of the discussion, as no.71 in the Institute's Special Report Series. The price of the volume will be announced later; a preprint of the paper will be sent to all those whose application for a bound volume is received by the Secretary before the meeting. Preprints will not be supplied separately.*

Members wishing to take part in the meeting should apply to the Secretary by not later than 22 November 1961.

Wednesday, 29 November

At the Federation of British Industries, Tothill Street, London SW1.

9.45–10.15
Formal business; election of members.

10.15–11.00
Symposium on the future of ironmaking in the blast-furnace
Introductory lecture by Dr T. P. Colclough, C.B.E.

11.00–1.00
Session I Injection processes
Presentation and joint discussion of
Blast-furnace performance with injection at the tuyeres, by J. M. Ridgion (BISRA)
Fuel-oil injection in a blast-furnace, by P. Hazard (Société des aciéries de Pompey, France)
Fuel-oil injection at Margam, by R. C. Sharp. (Steel Company of Wales Ltd)
Fuel-oil injection at Ebbw Vale, by W. C. F. Penry (Richard Thomas and Baldwins Ltd)
Principles of blast-furnace fuel injection, by N. B. Melcher and P. L. Woolf (US National Bureau of Mines).

2.30–5.00
Session II Hot-blast stoves
Presentation and joint discussion of:
Stove design and performance, by E. W. Voice (BISRA)
Hot-blast stoves, by J. S. Schofield, P. Butterfield, and P. A. Young (Head, Wrightson and Co. Ltd)
The high-temperature Cowper stove, by D. Petit (Société de Technique Industrielle, France)
Hot-blast stoves; some considerations in design and rating, by A. H. Dixon and B. S. Fowler (Ashmore, Benson, Pease and Co. Ltd)
A combined gas turbine/hot-blast stove, by C. Rounthwaite (Head, Wrightson and Co. Ltd).

Wednesday, 29 November

At the offices of the Institute, 4 Grosvenor Gardens, London SW1.

2.30–5.00

Session: The thermodynamics of slags

Presentation and discussion of the following papers (dates of publication in the *Journal* given in square brackets).

Thermodynamics of mixtures of ferrous sulphide and oxide, by E. W. Dewing and F. D. Richardson (Imperial College) [April 1960]
The thermodynamics of the conversion of magnesium and manganese oxides to sulphides, by E. W. Dewing and F. D. Richardson (Imperial College) [May 1960]
Activities of manganese oxide in silicate melts, by K. P. Abraham, M. W. Davies, and F. D. Richardson (Imperial College) [September 1960]
Sulphide capacities of silicate melts, by K. P. Abraham, M. W. Davies, and F. D. Richardson (Imperial College) [November 1960]
Activities in lime–alumina melts, by R. A. Sharma and F. D. Richardson (Imperial College) [August 1961]
The activity of calcium oxide in slags in the systems $CaO–MgO–SiO_2$, $CaO–Al_2O_3–SiO_2$, *and* $CaO–MgO–Al_2O_3–SiO_2$ *at 1500°C*, by M. R. Kalyanram, T. G. Macfarlane, and H. B. Bell (Royal College of Science and Technology, Glasgow) [May 1960]
The activity of ferrous oxide in silicate melts containing calcium and manganese oxides, by I. M. Davidson and C. Bodsworth (Liverpool University) [June 1960].

Thursday, 30 November

At the Federation of British Industries, Tothill Street, London SW1.

10.00–12.30

Session III Burden preparation

Presentation and joint discussion of:
Burden preparation for hematite iron and ferro-alloy production, by W. Hunter (Workington Iron and Steel Company)
Development of burden preparation in French blast-furnaces, by J. E. Astier, J. Michard, and P. Dancoisne (IRSID, France)
Increasing by 65% the productivity of blast-furnaces operating with heterogeneous burdens, by J. Boland (S. A. Cockerill-Ougrée, Belgium)
Blast-furnace performance using iron-ore pellets, by T. F. Olt (Armco Steel Corporation, USA).

2.30–5.00

Session IV Furnace engineering

Presentation and joint discussion of:
Developments in ironmaking and furnace design at Appleby-Frodingham from an engineering aspect, by A. Bridge (formerly of Appleby-Frodingham Steel Company)
Blast-furnace engineering development, by D. R. Brown and M. Adamson (Ashmore, Benson, Pease and Co. Ltd)
Blast-furnace refractories, by F. H. Aldred and P. R. Hinchliffe (Morgan Refractories Ltd).

Thursday, 30 November

At the offices of the Institute, 4 Grosvenor Gardens, London SW1.

10.00–12.30

Session on oxidation and scale

Presentation and joint discussion of the following papers (dates of publication in the *Journal* are given in square brackets).

The adherence of oxide films on metals, by R. F. Tylecote (King's College, Newcastle-upon-Tyne) [August 1960]

Factors affecting the adherence of oxides on metals, by R. F. Tylecote (King's College, Newcastle-upon-Tyne) [October 1960]

Marker movements in the oxidation of iron and some other metals, by R. F. Tylecote and T. E. Mitchell (King's College, Newcastle-upon-Tyne [December 1960]

A magnetite seam at the scale/metal interface on mild steel, by K. Sachs and G. T. F. Jay (GKN Group Research Laboratory) [June 1960]

Removal of scale from steel rod by stretching, by K. Sachs and T. Pitt (GKN Group Research Laboratory) [January 1961]

An X-ray high-temperature oxidation study on iron–copper, by H. J. Goldschmidt (BSA Group Research Centre) [December 1960]

The examination of oxide scales on iron–chromium alloys by X-ray scanning micro-analysis, by G. C. Wood (Cambridge University) and D. A. Melford (Tube Investments Research Laboratories) [June 1961].

2.30–3.30

Session on bainite

Presentation and joint discussion of:

Kinetic features of upper and lower bainite formation in a plain carbon and a 3%Ni–Cr steel, by J. S. White and W. S. Owen (Liverpool University) [May 1960]

The effect of austenite grain size and temperature on the rate of bainite formation, by J. Barford and W. S. Owen (Liverpool University) [February 1961]

The effect of up-quenching on the kinetics of bainite formation, by J. S. White and W. S. Owen (Liverpool University) [March 1961].

3.30–5.00

Session on alloy steels

Presentation and joint discussion of:

The bearing properties of 1%C–Cr steel as influenced by steelmaking practice, by R. F. Johnson (United Steel Companies Ltd) and J. F. Sewell (Samuel Fox and Co. Ltd) [December 1960]

The influence of non-metallic inclusions on the fatigue properties of ultra-high-tensile steels, by M. Atkinson (Steel Company of Wales Ltd) [May 1960].

Friday, 1 December

At the Federation of British Industries, Tothill Street, London SW1.

10.00–1.00

43rd Meeting of the Iron and Steel Engineers Group.

Presentation and discussion of the joint paper. Mr G. N. Hewett (McLellan and Partners) will give a general introduction to the paper. The various steelmaking processes will be dealt with as follows:

Conventional OH Oxygen OH LD with waste-heat boiler LD–AC	R. C. Aspland (Wellman-Smith-Owen Engineering Corporation Ltd)
LD without waste-heat boiler Kaldo and Rotor Bessemer with oxygen-steam	A. G. Raper (Davy and United Engineering Co. Ltd)
Electric steelplants of Brymbo type Electric steelplants using all cold metal	G. Ovens (McLellan and Partners).

EDUCATION

Universities
Technical colleges
Industry

Festival of technical and scientific films

An international festival of technical and scientific films is to take place in Budapest from 16 to 25 November. The organizing body, the Society of Mechanical Engineers, an affiliated organization of the Federation of Technical and Scientific Societies, invites films for inclusion in the festival programme. Films will be classified in the following groups: fundamental and natural sciences; technical applications of sciences; popular science and technics; educational; and research. The films will be shown in Budapest and eight other industrial centres, and will be judged by international juries who may award seven grands prix and 14 professional prizes. The closing date for the entry of films is 15 September, and any interested persons or bodies are advised to write for the explanatory brochure 'II international festival of technical and scientific films Budapest 1961' to the organizing committee at the following address: II Nemzetközi, Müszaki Tudományos Filmfesztivál, Rendezo Bizottság Irodája, Budapest V, Szabadság tér 17, Hungary. (Cables: FERBI Budapest).

Technological awards

The National Council for Technological Awards, which was set up by the Minister of Education in 1955, confers two awards: the Diploma in Technology, and Membership of The College of Technologists. The 'Dip.Tech.', which is equivalent to an honours degree of a British university, takes four years including an aggregate of one year of industrial training, and is designed for students aiming to become professional technologists; conditions of entry are flexible, but the student must be at least 18 years of age and likely to be successful in his studies. Membership of the College of Technologists is an award which is intended to stimulate students to undertake further study of a standard higher than that of the Dip.Tech. and the emphasis is again on close integration of academic study and industrial training and experience.

The original memorandum on these qualifications is now out of print, and a revised version (NCTA 1 revised) and further information may be obtained from the Secretary, The National Council for Technological Awards, 9 Cavendish Square, London W1.

BCAC Education and Training Panel

The Education and Training Panel of the British Conference on Automation and Computation is developing its work under three main headings: definitions, needs, and facilities (existing and required). Before estimates of manpower needs and required training facilities can be made, working definitions or examples of usage from a wide range of industries were needed; this aspect of the panel's work is now nearly complete.

The panel is also assisting the BCAC Executive Committee in the preparation of evidence for submission to the Committee on Higher Education, under the chairmanship of Lord Robbins.

Course: non-destructive testing

An evening course of 11 lectures on 'Techniques of non-destructive testing' is to be held in the Physics Department of Brunel College of Technology, Woodlands Avenue, Acton, London W3, every Wednesday, beginning on 4 October 1961.

The lectures will cover such topics as radiology, ultrasonics, eddy currents, magnetic methods, and thermal conductivity. They are intended for inspectors and others engaged in this type of work, and for graduates and holders of the HNC in engineering and science subjects who need an introduction to non-destructive testing. The fee for the course is £1. Further details may be obtained from the Physics Department at the above address.

NIFES course: solid fuel firing

The National Fuel Efficiency Service are to repeat their course on 'The latest developments in solid fuel firing'. The courses, which last for a week at a time, will begin on 2 October and 4 December 1961, and 5 February and 2 April 1962. They will be held at NIFES area office at 89 Oxford Street, Manchester. The fee, excluding hotel accommodation, will be 12 *gns*. Further information may be obtained from NIFES, 71 Grosvenor Street, London W1.

Radiation safety

The City and Guilds of London Institute has announced a new course on 'Radiation safety practice', designed for supporting staff engaged on health and safety duties in industries using radiation or radioactive materials. The first examination will be held in 1963, and full details of the syllabus are available from the Institute at 76 Portland Place, London W1.

NEWS | *Announcements and News of Science and Industry*

THE IRON AND STEEL INSTITUTE

Honour for President

The President (Sir Charles Goodeve, O.B.E., D.SC., F.R.S.) has been elected a Distinguished Life Member of the American Society for Metals. A presentation will be made to Sir Charles at the ASM banquet in Detroit on 26 October.

President-Elect

The Council of The Iron and Steel Institute have decided to nominate Mr M. A. Fiennes, M.I.MECH.E., Managing Director of Davy-Ashmore Ltd, at the Institute's Autumn General Meeting on 29 November 1961 for election at the Annual General Meeting, 2 May 1962, as President for 1962–1963.

Honorary Treasurer

At the Meeting of Council on 26 July, Mr H. W. A. Waring, C.M.G., General Managing Director and Deputy Chairman of GKN Steel Company Ltd, was elected Honorary Treasurer of The Iron and Steel Institute in succession to Sir Julian Pode, Deputy Chairman and Managing Director of The Steel Company of Wales Ltd. Sir Julian, who served as Honorary Treasurer since 1959, was elected a Vice-President of the Institute.

Special Meeting in the USA and Canada

The revised programme for this meeting was given on pp.420–422 of the August issue.

Autumn General Meeting 1961

The Institute's Autumn General Meeting and a meeting of the Iron and Steel Engineers Group will be held in London from **Wednesday 29 November** to **Friday 1 December 1961.** The programme is given on pp.77–78 of this issue.

Institute Meetings, 1962

Annual General Meeting 2 and 3 May

Autumn General Meeting 28 and 29 November

Special Meeting in Germany By invitation of the Verein deutscher Eisenhüttenleute the Institute will hold a special meeting in Düsseldorf from 2 to 8 July 1962 with short excursions before and after these dates. Further details will be published as soon as possible.

Joint meeting with the Institute of Fuel

A one-day joint meeting with the Institute of Fuel will be held on Wednesday, 13 February 1962, at the Institution of Civil Engineers, Great George Street, London SW1. The meeting will be in two parts, from 10 am to 12.30 pm, and from 2.30 pm to 5.30 pm, under the general topic 'Fuel and energy for various steelmaking processes'. Papers to be discussed have been published in the *Journal of the Institute of Fuel*. Titles and dates of publication will be given in the October issue of *JISI*.

Ablett Prize 1960

The Ablett Prize for 1960 has been awarded to C. Sturdy and A. A. Thomas (Davy and United Engineering Company Ltd), for their paper *The modern plate mill* (*JISI*, 1960, **194**, 486–494). Their co-author, M. F. Dowdin , was not eligible.

The Iron and Steel Institute Prize 1961

The award of the Iron and Steel Institute Prize for 1961 has been made to R. B. Cundill, of Skegness, Lincs. Mr Cundill received the degree of B.MET. with first class honours at Sheffield University in July of this year.

NEWS OF MEMBERS

Dr **B. B. Argent** of the Department of Metallurgy, University of Sheffield, is to be visiting assistant professor at the Department of Mineral Technology, University of California, for the next academic session. He will return to Sheffield in September 1962.

Mr **J. D. Bolckow** has been appointed general manager of Redpath Brown and Co. Ltd, and a special director of Dorman Long and Co. Ltd.

Mr **A. Bridge,** ironworks engineer at Appleby-Frodingham Steel Company, retired on 30 June 1961.

Mr **N. R. R. Brooke** has been appointed to the local board of directors of John Lysaght's Scunthorpe Works Ltd.

Professor **Georges Chaudron** has been elected honorary president of the Société Chimique de France.

Mr **J. F. Crittall,** J.P., has been appointed a director of Darlington and Simpson Rolling Mills Ltd.

Mr **P. Dixon,** steelworks engineer at Appleby-Frodingham Steel Company, retired on 30 June 1961.

Mr **H. H. England** has resigned from the position of manager of the Templeborough melting shop of Steel, Peech and Tozer.

Monsieur **Pierre Épron** has been appointed vice-president of the Société des Aciéries de Longwy. He has also been elected president of the Conseil National des Ingénieurs Français.

Mr **G. Foster** has been appointed an executive director of Dorman Long and Co. Ltd.

Dr **R. Genders** has been elected to the board of Arnott and Harrison Ltd.

Mr **E. S. Greenhill,** plant engineer at the Appleby-Frodingham Steel Company, retired on 30 June 1961.

Mr **D. W. Hammond** has retired from his directorship of Jessop-Saville Ltd.

Mr **C. Hipwell** has retired from his executive position on the board of Dorman Long and Co. Ltd; he remains a director of Redpath Brown and Co. Ltd.

Mr **R. S. Howes** is vice-president of the Electric Steel Makers' Guild.

Mr **G. P. Jones** has joined Esso Petroleum Ltd, as manager, steel industry sales.

Mr **W. Keen** has been elected president of the Electric Steelmakers Guild.

Lord **Riverdale of Sheffield** is relinquishing his appointment as managing director of Arthur Balfour and Co. Ltd, but is retaining the position of chairman (henceforth to be known as executive chairman).

Dr **J. Sawkill** has left Tube Investments Research Laboratories to join Accles and Pollock Ltd.

Mr **H. Simms,** personal assistant to the general works manager, Appleby-Frodingham Steel Co., is returning to the metallurgical department. He will be seconded to special duties in connexion with the rod/bar mill.

Mr **S. S. Smith** has been appointed executive director and general manager of Nuclear Developments Ltd.

Col. **Robert A. Solborg** has retired from the board of Armco Ltd.

Mr **George Talbot** has been appointed deputy managing director of Stein and Atkinson Ltd.

Mr **J. D. Wright** has been appointed manager of the Templeborough melting shop of Steel, Peech and Tozer.

Davy-Ashmore Ltd

Mr D. F. Campbell (*Honorary Vice-President*) chairman of Davy-Ashmore Ltd, has announced his intention to retire from the board at the conclusion of the forthcoming annual general meeting in September. Mr M. A. Fiennes (*Member of Council*) is to succeed him as chairman, and Mr L. H. Downes is to be vice-chairman.

United Steel Companies

The United Steel Companies Limited have announced that Mr Stafford Beer (*Member*), who has been head of the company's department of operational research and cybernetics since its inception in 1957, has resigned to become managing director of a new international firm of operational research consultants based in London. Mr D. G. Owen, previously assistant head of the department, succeeded Mr Beer from 1 August.

Award from ASTM

An Award of Merit of the American Society for Testing Materials has been given to Thomas E. Eagan (*Member*), chief research metallurgist, The Cooper Bessemer Corp., Grove City, Pa., USA, for outstanding contributions to the field of ferrous metals.

BRITISH IRON AND STEEL ASSOCIATION

Conference: Hydrogen in steel

Professor A. R. Troiano, of the Case Institute of Technology, Cleveland, USA, will give the opening lecture, dealing with the role of hydrogen in the mechanical behaviour of metals, at the BISRA conference on 'Hydrogen in steel', which will be held at Harrogate from 11 to 13 October 1961.

The programme includes five other subjects:

Removal of hydrogen from liquid and solid steel

Effect of hydrogen on the properties of ultra high-tensile steels

Diffusion and solubility of hydrogen in steel

Hydrogen in weld metal

Unresolved factors about hydrogen in steel.

Full details of the arrangements, and application forms, may be obtained from: The Technical Secretary, Metallurgy Division, BISRA, 11 Park Lane, London W1.

BRITISH CONFERENCE ON AUTOMATION AND COMPUTATION

Dr D. G. Christopherson, O.B.E., F.R.S., Pro-Vice-Chancellor of The University of Durham and Warden of the Durham Colleges, will give the first annual lecture of the British Conference on Automation and Computation. He will speak on the subject: 'Mathematics—friend or foe?' at the lecture theatre of the Institution of Electrical Engineers, Savoy Place, London WC2, on Wednesday, 27 September 1961 at 5.30 pm. Tea will be served at 5 pm.

The lecture is open to all members of the 31 societies of BCAC, and others may apply for free tickets to the Hon. Secretary, BCAC, c/o The Institution of Electrical Engineers, Savoy Place, London WC2.

INSTITUTE OF METALS

Autumn meeting in Brussels

The programme of the Institute's 53rd annual meeting, which is being held from 18 to 22 September of this year in the Palais de Congres, Coudenberg, Brussels, is now available. The programme contains details of the scheduled technical sessions, and of the social occasions and excursions which will form part of the meeting. Brief synopses of the papers to be discussed at the meeting, with notes on the nature of the works in Belgium that will be visited, are also included. Requests for further information should be made to The Institute of Metals, 17 Belgrave Square, London SW1.

Conference: the metallurgy of beryllium

An international conference on 'The Metallurgy of beryllium', organized by The Institute of Metals, will be held at the Royal Commonwealth Society, Craven Street, London, from 16 to 18 October 1961. The first day and a half of the conference will be devoted to the mechanical and physical properties of beryllium and 26 papers are expected in this section. On the afternoon of 17 October, the discussion will be concerned with the use of beryllium in reactors, with 17 papers on the topic, and with its use in aircraft and missiles, 3 papers. The topic for the third day will be metal preparation and fabrication, and there will be about 30 papers on this topic. Preprints of the papers will be available to all who register for the conference; a registration fee will be charged.

POWDER METALLURGY JOINT GROUP

Winter meeting

The title of the symposium which has been arranged by the Powder Metallurgy Joint Group for the winter meeting will be 'Sintered high-temperature compounds'. The symposium will take place on 8 December; on the previous day, 7 December, there will be a half-day discussion based on four papers submitted to *Powder Metallurgy* for publication.

THE INSTITUTE OF PHYSICS AND THE PHYSICAL SOCIETY

Council elections

At the first annual general meeting of the institute and society the following were elected to office: *President* Sir John Cockcroft, *Vice-Presidents* Dr V. E. Coslett, Professor R. W. Ditchburn, Dr W. H. Taylor, and Dr J. Topping, *Honorary Treasurer* Dr J. Taylor, *Honorary Secretary* Dr C. G. Wynne. Eight members of council were also elected, and the composition of this first elected council is very nearly the same as that of the 'caretaker' council which has held office during the first few months of the amalgamated body.

Annual report 1960

The Institute of Physics and the Physical Society were amalgamated during July 1960; the annual report 1960 of the amalgamated body contains details of activities both before and after amalgamation, including conferences, symposia, and other meetings, and the publications for which the institute and society are responsible, notably the report 'The postgraduate training of physicists in British universities' and the fifth survey of salaries received by members of the professional grades. The report is available from The Institute of Physics and The Physical Society, 47 Belgrave Square, London SW1.

The Institute and Society have announced several meetings, which are briefly noted below. Further details may be obtained from the Administration assistant, The Institute of Physics and The Physical Society, 47 Belgrave Square, London SW1.

Conference: radiospectroscopy of solids

A two-day conference on 'Radiospectroscopy of solids' is to be held by the Institute and Society at the Department of Physics, University College of North Wales, Bangor, on 21 and 22 September 1961. During the conference the Guthrie lecture, on 'The de Haas–van Alphen effect and the electronic structure of metals' will be presented by Dr D. Schoenberg, F.R.S.

Symposium: some aspect of the physics of space research

A residential symposium on 'Some aspects of the physics of space research' is to be held at the Royal Military College of Science, Shrivenham, Swindon, Wiltshire, from 20 to 22 September 1961. The subjects include: the advantages to physicists of space research; cosmic rays, particle physics, and meteorology; radio research from rockets and satellites; and rockets, orbits, and trajectories.

Conference: the physics of gas discharge devices

The electronics group of the Institute and Society are to hold a conference on 'The physics of gas discharge devices', in the assembly room, the Town Hall, Leamington Spa, on 28 and 29 September 1961. The introductory address will be given by Professor J. D. Craggs, F.INST.P., of the University of Liverpool. Other lecturers will be from Liverpool, Swansea, and Sheffield universities, and from AEI, Mullard, and GEC research laboratories. There will be a visit for a limited number to AEI laboratories at Rugby.

Those wishing to attend must make their own arrangements for hotel accommodation. The Regent Hotel, The Parade, Leamington Spa, will be the headquarters of the conference. Registration is necessary and the closing date is 8 September 1961. Lists of hotels, programmes of the conference, and application forms are available.

ASSOCIAZIONE ITALIANA DI METALLURGIA

Move to new premises

The Associazione Italiana di Metallurgia has moved to the building of the Federation of Scientific and Technical Associations at Via del Politecnico 10, Milan. Other organizations which have also transferred to this address include the National Commission for Industries Research of the CNR; the Lombard sections of the Italian Electro-Technical Association; the Association of Chemical Engineers; the Association of Mechanical Engineers; the Italian Thermotechnical Association; the Italian Chemical Society; the Italian Physical Society; and the Italian Thermotechnical Committee.

The new building houses the joint library of all the societies in occupation.

Council, 1961–62

At the annual general meeting of the association for 1961, the new council of the Associazione Italiana di Metallurgia was elected. The elections to the major offices were as follows: *President* Prof. A. Scortecci (*Member*), *Vice-presidents* Prof. C. Panseri (*Member*) and Ing. V. Ventafridda, and *Secretary* Dr G. Gavioli (*Member*).

THE SOCIETY OF CHEMICAL INDUSTRY

Industrial water and effluents group

Under the chairmanship of Dr B. A. Southgate, a new subject group of the Society of Chemical Industry, to be known as the Industrial Water and Effluents Group, is being formed. The group will be interested in all aspects of the science and technology of treatment, conservation, and economic use of water, and of the treatment and disposal of effluents. A programme of meetings is being arranged for the 1961–62 session; the first meeting will take place at the Royal Institution, 21 Albemarle Street, London W1, on 1 November 1961.

Anyone interested in membership of the group should write to the General Secretary, Society of Chemical Industry, 14 Belgrave Square, London SW1, or to the Industrial Water and Effluents Group Secretary, J. L. Hewson, at Imperial Chemical House, Millbank, London SW1, from whom further information and application forms may be obtained.

THE INSTITUTE OF WELDING

Council elections

At the annual general meeting 1961 of the Institute of Welding, Mr H. West, M.SC., managing director of AEI (Manchester) Ltd, was installed as president of the institute for 1961–62. Two new vice-presidents also took office at the meeting: Mr C. Humphrey Davy (*Member*) and Mr L. Redshaw. The following were elected to the council: E. V. Beatson, M. Birkhead (*Member*), V. W. Clack, A. Evitts, S. H. Griffiths (*Member*), J. J. Hooper (*Member*), J. McLean, and Dr R. Weck.

Welding in shipbuilding

The joint symposium on welding in shipbuilding, announced in the July issue of the *Journal*, which is being organized by the Institute of Welding, will be held during the week 30 October to 3 November 1961. Thirty-four papers, many by foreign authors, dealing with aspects of design, construction, and quality control will be presented and discussed at eight technical sessions; all the papers will be preprinted and the proceedings including a report of the discussions will be published in 1962. The definitive programme will be circulated during September, and inquiries should be addressed to the Institute of Welding, 54 Princes Gate, London SW7.

BRITISH WELDING RESEARCH ASSOCIATION

New research laboratory

A new 21 000 ft^2 engineering laboratory was recently opened at Abington Hall, headquarters of the BWRA near Cambridge. The opening was combined with a two-day exhibition of work in progress. Increasing applications of welding and the complexity of many of the techniques required has meant a considerable increase in the association's projects. Included among the exhibits was a friction welder built by the association, an electro-slag welder, a high-speed arc plasma jet, and some spectacular weld testing machines.

BRITISH STEEL CASTINGS RESEARCH ASSOCIATION

Council elections

Mr W. S. Scott, M.A., managing director of Darlington Forge, has been elected chairman of the council of the BSCRA, in succession to Dr R. Hunter (*Member*). Dr C. J. Dadswell (*Member*) becomes vice-chairman of the council.

Annual report 1961

The eighth annual report of the BSCRA covers a period (1 April 1960–31 March 1961) which has been mainly one of consolidation following extensions to plant and equipment that took place during the previous year. New plant and equipment, a considerable reorganization of administration, and the research that was continued during the past year, are briefly outlined. Appendixes include the research programme of the association for 1961–62, and details of publications which were published during the period covered by the report, which is available from the British Steel Castings Research Association, 5 East Bank Road, Sheffield 2.

BRITISH COKE RESEARCH ASSOCIATION

Annual report 1960

The seventeenth annual report of the BCRA includes the association's report of council and report of the director for the year ended 31 December 1960. Activities of the association during the year are described, and an outline given of the work carried out in the laboratories and by the Coke Research Fellows at Hull and Sheffield Universities. The report is available from The British Coke Research Association, Chesterfield, Derbyshire, or from the association's registered office at 74 Grosvenor Street, London W1.

CONTRIBUTORS TO THE JOURNAL

Sir Leonard Owen, C.B.E., K.B., M.ENG.—Member for Production and Engineering, UKAEA.
Sir Leonard Owen was born in 1897 at Liverpool and was educated at the Liverpool Collegiate School and Liverpool University. From 1915 to 1918 he served with the 6th King's Liverpool Regiment. In 1922 he joined the engineering department of Brunner, Mond and Co., (later ICI (Alkali) Ltd), where he was engaged on designing new chemical plants and additions to existing chemical plant. In 1940 while still on the staff of ICI he worked at the Ministry of Supply as engineering director of the Royal Filling Factories; the job entailed the building and modification of these factories to meet the ever-changing needs of the services. In 1946 he became Director of Engineering in the Department of Energy Production at the Ministry of Supply, and the next year the department's Assistant Controller.

In August 1954 he became Director of Engineering and Deputy Managing Director of the United Kingdom Atomic Energy Authority Industrial Group at Risley, and in September 1957 Managing Director of the Group. In July 1959 he was appointed Member for Production, UKAEA, and in April 1961 the responsibility for engineering was added to this post.

Sir Leonard is a Member of Council of the Institution of Civil Engineers, and a member of the Institution of Mechanical Engineers, and of the Institution of Chemical Engineers.

V. J. Moran, B.SC., A.S.T.C.—Lecturer in Metallurgy, University of New South Wales, Sydney.
Born in 1924 and educated at St Peter's College, Adelaide, V. J. Moran joined the staff training scheme of the Broken Hill Propriety Company, iron- and steelworks, Newcastle, NSW, and worked for eight years in blast-furnace, open-hearth, and research departments, the period being broken by three years in the Royal Australian Air Force. He graduated from the Sydney Technical College as an Associate in 1952 and from the University of New South Wales as Bachelor of Science in 1953, joining the lecturing staff of the latter in 1954. He is at present on leave as Tube Investments Research Fellow at the University of Sheffield.

A. E. Jenkins, B.MET.E., M.ENG.SC., PH.D.—Associate Professor in charge of Metallurgical Engineering, University of New South Wales.
A. E. Jenkins joined the staff of the university in 1955. After a period of service in the Royal Australian Air Force, he graduated from the University of Melbourne in 1949 and was formerly Research Officer at the Commonwealth Scientific and Industrial Research Organization, Baillieu Laboratories, Melbourne.

NEWS OF SCIENCE AND INDUSTRY

New creep of steel laboratory

The formal opening on 6 July 1961 of the new creep of steel laboratory at Leatherhead marked a further stage in the development of the Electrical Research Association, which began in 1921 when the first experimental station for circuit-breaker research was opened at Carville.

The new 9900 ft^2 laboratory has been financed by BISRA, the CEGB, the Water-Tube Boilermakers' Association, and commercial turbine and pipemakers, with the addition of a capital grant from DSIR. Its object is to improve efficiency in generating electricity, chiefly in steam-driven and turbo-alternator sets. The laboratory is equipped with 50 high-sensitivity creep machines, with optical extensometers; 50 ten-specimen rupture machines, and 50 dual-purpose machines for either dial gauge creep measurements or three-specimen multi-rupture. In addition there is one 15-ton creep machine for testing specimens from the full wall thickness of steam pipes, and 11 rigs for testing tubes stressed by internal steam pressure while at high temperature.

Company news

BARCON (Barrow Steel Works Arc Furnace Continuous Casting), is the code name that The United Steel Companies have given to what will, when completed, be the first works in the world to be wholly dependent on continuously cast steel for its rolling mills. A pilot continuous casting unit was installed at Barrow Steel Works in 1952; since 1954 United Steel has borne the operating cost of the experimental work. Now that United Steel has purchased the steelworks from the Iron and Steel Holding and Realization Agency, for £2 200 000, the process, which is working successfully, is to be expanded. Two full-scale twin-strand continuous casting machines and a 20-ton electric arc furnace are being installed: the plant is expected to come into operation shortly.

Metals Division of Kelsey-Hayes sold

A new company, Special Metals, Inc., has been formed in New York and has purchased the Metals Division of the Kelsey-Hayes Company. The new company will specialize in vacuum metallurgy, continuing the work of the Metals Division which was one of the pioneers of vacuum induction melting. President of Special Metals is Dr F. N. Darmara (*Member*), who was formerly president and general manager of the Metals Division.

Contract News

Air Products Ltd are to build a tonnage oxygen plant of 125 tons/day capacity for the Shelton Iron and Steel Co., as part of Shelton's £18 m. development plan.

Spun iron pipes worth £200 000 are being supplied to the city authorities of Alexandria, Egypt, by *Stanton Iron Works Ltd* for extensions to the city's sewage system.

Loewy Engineering Co. Ltd, of Bournemouth, have received an order for three extrusion presses to West Germany, the total value of which is £½ m.

Corrigendum

In the first item under 'Contract News', p.425 of the August issue of the *Journal*, Lodge Cottrell Ltd were described as having supplied four boilers for Tilbury power station, whereas they supplied the precipitators for these boilers.

New plant and equipment

In the Wallsend-on-Tyne shipyards of Swan, Hunter, and Wigham Richardson Ltd, the first two British machines to weld plates automatically vertically, are now in service. Using electro-slag welding, the machines were developed and manufactured by the *British Oxygen Company*.

A three-phase, three-electrode electric steel furnace, the largest in the world, has been designed by Soviet engineers, according to *Tass*. Scheduled for service in 1965, it will produce about 250 000 tons of top-quality steel a year.

The largest electric-arc melting furnace in the UK, designed and built by *Birlec-Efco (Melting) Ltd*, has begun work at the River Don works of The English Steel Corporation Ltd. The furnace has a shell dia. of 21 ft, electrical rating of 20 MVA, and can melt a 90-ton charge in less than 3 h.

The new electrolytic tinning line at the Ebbw Vale works of *Richard Thomas and Baldwins Ltd* has produced tinplate in coil form, but will be further run-in before full production is begun. The line permits coating of up to 16 oz. tin per basis box, and can give differential coatings on either side of the sheet.

Appleby-Frodingham Steel Company's new universal beam mill engineered by *Schloemann AG* is now in production. Most controls are automatic, roll changing is quick, all rolls are mounted in roller bearings, and the mill can roll wide-flange beams with parallel flanges up to 24in × 9in, columns up to 12in × 12in, and corresponding junior beams.

INDUSTRIAL PUBLICATIONS RECEIVED

Colvilles Magazine, Summer 1961, contains a historical article on the centenary year of the Gattcosh Sheet Works of Smith and Maclean, the site of the new Colvilles strip mill; the progress of cold reduction plant of the new mill is outlined in another article in the same issue.

Tollcross steel foundry, published by Stewarts and Lloyds, is an illustrated booklet outlining the range of plant and products at the foundry of the title.

FORTHCOMING CONFERENCES AND EXHIBITIONS

Conference: fatigue, strength, and fracture

The Hungarian Academy of Sciences is arranging a conference on 'Problems of dimensioning and strength calculation' which will take place at the academy in Budapest from 24 to 28 October 1961. The main topics for discussion will be: testing and estimating of fatigue life and fatigue strength; and impact testing and strength calculation of machine under dynamic loads and problems of brittle fracture. The lecturers will be from France, USA, USSR, Czechoslovakia, the UK, Hungary, Italy, Sweden, and Germany. The official languages of the conference are: English, German, Hungarian, and Russian. A programme of the conference is available from: the Secretary of the conference, Magyar Tudományos, Akadémia Müszaki Tudományok Osztálya, Budapest V, Nádor utca 7. (Hungary). The programme outlines the cost of attendance, and of tours and excursions arranged by the organizing body.

Indian industries fair 1961

The Federation of Indian Chambers of Commerce and Industry, with the active support of the Indian Government, is to arrange an Indian industries fair at New Delhi from 14 November 1961 to 1 January 1962. Besides Indian exhibits many exhibits are expected from foreign suppliers and manufacturers, particularly since the third five-year development plan will have begun shortly before. Further particulars, and copies of the rules and regulations, may be obtained from the Secretary, Indian Industries Fair, Federation House, New Delhi 1, or from the High Commission of India, Commerce Department, India House, Aldwych, London WC2; and details of exhibitors from the UK may be obtained from the Export Publicity and Fairs Branch of the Board of Trade, Horse Guards Avenue, London SW1.

DIARY

3–10 Sept. AUTUMN FAIR, Leipzig.

4–9 Sept. TECHNISCHE HOCHSCHULE, KARLSRUHE—5th International conference on ionization phenomena in gases—Munich.

9–18 Sept. CZECHOSLOVAK SCIENTIFIC AND TECHNICAL SOCIETY—International symposium on corrosion-resisting steels and alloys—Prague.

18–22 Sept. INSTITUTE OF METALS—Autumn meeting — Palais des Congres, Coudenberg, Brussels.

21–22 Sept. INSTITUTE OF PHYSICS AND PHYSICAL SOCIETY—Conference, 'Radio-spectroscopy of solids'—University College of North Wales, Bangor.

20–22 Sept. INSTITUTE OF PHYSICS AND PHYSICAL SOCIETY—Symposium, *'Some aspects of the physics of space research'*—Royal Military College of Science, Shrivenham, Swindon, Wilts.

26 Sept.–6 Oct. HEATING, VENTILATING, AND AIR CONDITIONING EXHIBITION—Olympia, London.

27 Sept. BOAC—Annual lecture, *'Mathematics–friend or foe?'*, by Dr D. G. Christopherson, O.B.E., F.R.S.—Lecture theatre, Institution of Electrical Engineers, Savoy Place, London WC2, 5.30 pm.

28–29 Sept. INSTITUTE OF PHYSICS AND PHYSICAL SOCIETY—Conference, *'The physics of gas discharge devices'*—Assembly room, Town Hall, Leamington Spa.

29 Sept.–15 Oct. BRITISH TRADE FAIR—Mexico City.

2 Oct. INSTITUTE OF BRITISH FOUNDRYMEN—Presidential address by Dr R. V. Riley—Annexe, Sheffield College of Technology, Pond St., Sheffield 1, 7 pm.

4–12 Oct. ELECTRONIC COMPUTER EXHIBITION AND BUSINESS COMPUTER SYMPOSIUM—Olympia, London.

11–12 Oct. OPEN DAYS—Water pollution research laboratory—(Apply: Director, Water pollution research laboratory, Elder Way, Stevenage, Herts.

11–13 Oct. BISRA CONFERENCE ON HYDROGEN IN STEEL—Old Swan Hotel, Harrogate.

13 Oct. WEST OF ENGLAND METALLURGICAL SOCIETY—Lecture, *'Creep: the potential influence of theory in practice'*, by Dr D. McLean – College of Technology, Ashley Down, Bristol 7.

14 Oct. NORTH OF ENGLAND INSTITUTE OF MINING AND MECHANICAL ENGINEERS—Lecture, *'The instrumentation of a methane drainage system'*, by H. S. Shillingford—Lecture theatre, Neville Hall, Newcastle upon Tyne, 2.30 pm.

16–18 Oct. INSTITUTE OF METALS—Symposium, *'The metallurgy of beryllium'*—Royal Commonwealth Society, Northumberland Avenue, London WC2.

BRITISH IRON AND STEEL INDUSTRY TRANSLATION SERVICE

The following translations are now available, in addition to those given on pages 425 and 426 of the August 1961 issue of the *Journal*.

When ordering, please quote the number in bold type.

Stress relaxation in heat-resisting austenitic steels. (From Czech.) PECH, R., *Hutn. Listy* (Prague), 1959, *14*, (12), pp.1119–1121. (£4) **[1674**

The proper dimensioning of ball and roller bearings for stands in continuous section, wire, and strip mills. (From German.) PAUELS, H., and ROHDE, H. H., *Stahl Eisen*, 1960, *80*, March 31, pp.417–428. (£8) **[1710**

On the causes of wear of tools. (From German.) OSTERMANN, G., *Industrie-Anzeiger*, 1959, (62), pp.13–21. (£6 10*s*. 0*d*) **[1761**

Investigations into the recrystallization of a ferritic 27%Cr steel with special reference to annealing time (with bibliography, 35 refs). (From German.) BORCHERS, H., *et al.*, *Arch. Eisenhüt.*, 1960, *31*, March, pp.177–192. (£4) **[1836**

Rapid method for the determination of lead in free-cutting steel. (From German.) MEYER, S., and KOCH, O. G., *Arch. Eisenhüt.*, 1958, *29*, Nov., pp.677–682. (£3 10*s*. 0*d*.) **[1894**

Effect of obstructions to flow (liquids) in the intake upon the heat transfer in tubes and annular clearances. (From German.) GRASS, G., *Atomkern-Energie*, 1958, *3*, (10), pp.382–388. (£4 15*s*. 0*d*.) **[1900**

The weighing of goods wagons, particularly of those in motion, on inclined rail weighbridges. (From German.) MASSUTE, E., *ETR* Sonderausgabe 11, 1959, Sept., pp.57–67. (£6 5*s*. 0*d*.) **[1944**

A new blast-furnace with 9 m hearth diameter (for discussion see BISI 1716 Heynert *et al.*) (From German.) WINTERS, C., *Stahl Eisen*, 1960, *80*, April 14, pp.465–473. (£4 5*s*. 0*d*.) **[1962**

Mathematical analysis of the degassing of specimens held under vacuum at constant temperatures. (From French.) CALMETTES, J. *et al.*, *Rev. Mét. Mém. Sci.*, 1960, *57*, Sept., pp.659–675. (£4 15*s*. 0*d*.) **[1981**

The phosphate coating process and its effect on the fatigue strength of steel. (From German.) TAUSCHER, H., *Draht*, 1960, *11*, Nov., pp.442–448. (£4) **[2013**

State of knowledge on the properties of steels for high-pressure hydrogenation vessels. (From German.) CLASS, I., *Stahl Eisen*, 1960, *80*, Aug. 18, pp.1117–1135. (£8) **[2060**

Choice of materials for the parts of high and super-high pressure accessories subjected to wear. (From Russian.) RATNER, A. V., and LEONOVA, L. G., *Teploenergetika* (Moscow) 1960, Dec., pp.14–18. (£3 10*s*. 0*d*.) **[2065**

Mechanism of the electrical breakdown of metal suspensions in liquid dielectrics. (From Russian.) GINDIN, L. G. *et al.*, *Dok. Akad. Nauk SSSR*, 1950, *74*, (1), pp.49–52. (£2 5*s*. 0*d*.) **[2075**

Contributions of German steelworks to the development of heavy forgings. (From German.) GUMMERT, H., *Stahl Eisen*, 1960, *80*, Oct. 27, pp.1517–1524. (£5 10*s*. 0*d*.) **[2076**

Bending and the rigidity of valve component covers freely or flexibly suspended, suitable for blast-furnace equipment. (From Russian.) STOROZHIK, D. A., *Izvest. VUZ Chern. Met.*, 1959, (9), pp.157–169. (£5 5*s*. 0*d*.) **[2084**

Modern electronic weighing. (From German.) WIETHOFF, G., *Werkstattstechnik*, 1960, *50*, (10), pp.537–547. (£7 10*s*. 0*d*.) **[2093**

Methods of influencing the oxygen content of soft open-hearth steels during refining. (From German.) HESS, W., *Stahl Eisen*, 1961, *81*, Jan. 19, pp.103–110. (£4 15*s*. 0*d*.) **[2094**

Comparison of results obtained by subjecting mild steels to the cup-forming and the Erichsen deep-drawing tests. (From French.) KRÜGER, A., Colloquium on the shaping of sheet metal International Deep Drawing Research Group, Société Française de Mét., Paris, May 23–25 1960. (£5 10*s*. 0*d*.) **[2095**

The obtaining of niobium nickel alloys by the reduction of niobium pentoxide in the presence of nickel. (From German.) GRUBE, G., *et al.*, *Zeitschrift für Elektrochemie u. Angewandte Physikalische Chemie*, 1939, Dec., pp.881–884. (£3) **[2099**

The influence of small amounts of nickel and chromium on the mechanical properties of steel. (From Japanese.) OHTAKE, T. *et al.*, *Tetsu to Hagane*, 1959, *45*, Sept., pp.1089–1092. (£8) **[2105**

The importance of noise measurement for the effective abatement of noise nuisance in the iron and steel industry. (From German.) SCHULZ, G., *Stahl Eisen*, 1961, *81*, Feb. 16, pp.220–228. (£5 15*s*. 0*d*.) **[2109**

Control of sinter plant operation. (From German.) WEILANDT, B., and PETRUSCH, N., *Stahl Eisen*, 1961, *81*, Feb. 16, pp.235–238. (£3 10*s*. 0*d*.) **[2112**

Report on experience with the measurement of blast-furnace lining wear by means of radioactive isotopes. (From German.) FLOSSMANN, R., and GEIDEL, R., *Stahl Eisen*, 1960, *80*, Nov. 24, pp.1753–1759. (£4 10*s*. 0*d*.) **[2113**

The calculation of brick temperatures in air pre-heaters. (From German.) HAUSEN, H., *Arch. Eisenhüt.*, 1938–9, *12*, (10), pp.473–480. (£5 15*s*. 0*d*.) **[2115**

Melting, casting, and heat-treatment of fully austenitic cast nickel–iron–chromium alloys containing molybdenum and copper. (From German.) ROESCH, K., and SCHMITZ, K.-H., *Giess. Tech. Wiss.*, 1961, *13*, Jan., pp.43–55. (£8) **[2117**

The effect of phosphorus on some properties of austenitic chromium–nickel steel. (From Russian.) PRIDANTSEV, M. V., and LITVINENKO, D. A., *Spetsial'nye Stali i Splavy*, Tsentr. Nauch.-Issled. Inst. Chernoi Met., Metallurgizdat, 1960, (17), pp.386–397. (£4 5*s*.) **[2127**

The kinetics of pitting in passivated nickel–chromium steel. (From German.) BRAUNS, E., and SCHWENCK, W., *Werks. Korr.*, 1961, *17*, Feb., pp.73–80. (£4 5*s*. 0*d*.) **[2128**

The thickness of the zinc coating and the corrosion resistance of hot dip galvanized parts. (From German.) HAARMANN, R., *Metalloberfläche*, 1959, *13*, Nov., pp.342–345. (£2 10*s*. 0*d*.) **[2131**

Manufacture and quality of special steel tubes for high temperature and high pressure service. (From Japanese.) HARADA, K., *Sumitomo Metals* (Osaka), 1960, *12*, April, pp.80–90. (£10) **[2144**

Reinforced concrete sleepers on German Federal Railways. (From German.) NEUMANN, B., *Der Eisenbahn-Ingenieur*, 1961, March, pp.68–75. £5 10*s*. 0*d*.) **[2145**

Physical problems in the conveying of solid particles in liquids and gases. (From German.) BARTH, W., *Chemie-Ingenieur-Technik*, 1960, *32*, March, pp.164–171. (£3 15*s*. 0*d*.) **[2152**

Study with models of the speed of mass transfer between metal and slag in the making of steel. (With discussion.) (From French.) ROCQUET, P., and ADAM-GIRONNE, J., *Rev. Mét.*, 1960, *57*, Dec., pp.1081–1089. (£3 10*s*.) **[2153**

The screening of hot sinter. (From Russian.) RUDAKOV, L. M., and GORSHTEIN, J. J., *Metallurg*, 1961, *6*, Feb., pp.3–4. (£1 10*s*. 0*d*.) **[2154**

Mechanical properties of martensitic 13% nickel steel at liquid air temperatures. (From German.) SCHUMANN, H., *Neue Hütte*, 1961, *6*, Feb., pp.92–98. (£4 15*s*. 0*d*.) **[2173**

Pneumatic transport of ash. (From German.) TRENKLER, H., *Braunkohle Wärme und Energie*, 1960, *12*, Feb., pp.59–64. (£4) **[2231**

Manufacture, properties and application of semi-killed steel. (From German.) FELLCHT, K., and ECKSTEIN, H. J. (*Neue Hütte*, 1960, *5*, Oct., pp.590–596. (£4) **[2274**

The choice of furnaces and fuel for the magnetic roasting of Krivoi Rog quartzites. (From Russian.) MAKHORIN, K. E., and BUGAENKO, B. P., *Metallurg*, 1960, *5*, Oct., pp.3–7. (£3 10*s*. 0*d*.) **[2289**

The use of fuel oil in blast-furnace production. (From Russian.) Part 1, MALIKOV, K. V. *et al.*, Part 2, SAPIRO, S. I. *et al.*, *Metallurg*, 1961, May, pp.3–7. (£3 15*s*. 0*d*.) **[2291**

On the metallurgy of the basic converter process. (From German.) OELSEN, W., and MAETZ, H., *Arch. Eisenhüt.*, 1948, *19*, pp.111–117. (£5 10*s*. 0*d*.) **[2292**

The influence of aerodynamics on dust deposition in slag pockets and vertical uptakes. (From Russian.) GLINKOV, M. A., and REKHTMAN, A. Ya., *Izvest. VUZ Chernaya Met.*, 1961, (3), pp.161–171. (£5 5*s*. 0*d*.) **[2296**

Thermal stressing of a mandrel during the extrusion of tubes. (From German.) LEIFELD, B., *Z. Metallk.*, 1960, *51*, Dec., pp.674–676. (£2 10*s*. 0*d*.) **[2302**

ABSTRACTS OF CURRENT LITERATURE AND BOOK NOTICES

Iron and Steel Manufacture and Related Subjects

CONTENTS

Note: The letters *a*, *b*, and *c* refer to the three columns on the page concerned.

* Abstracts, the reference to which is marked with an asterisk, are or are to be made available as translations.

ABSTRACTS

These abstracts are also available on index cards in advance of publication in the *Journal*, each abstract being classified under the Universal Decimal system (UDC). Details and subscription notes can be obtained from the Secretary, The Iron and Steel Institute.

MINERAL RESOURCES

Description, age and metallogenesis of the iron ore body at Milhas (Hauge-Garonne) J. Thiébaut and M. Weppe (*Compt. Rend.*, 1961, **252**, March 20, 1813–1814) A brief description of the characteristics of the iron ore deposit at Milhas in the Central Pyrenee 15 km S.E. of Saint-Gandeus, is presented, and compared with those of the neighbouring deposit at Lastric which resemble it.—S.H.-S.

Survey of the Canadian iron ore industry during 1959 R. B. Elver (*Can. Mines, Min. Inform. Bull.*, MR 45, pp.121, 1960) Three new mines have been brought into production during this period and Canada ranks fourth as world producer, the order being Russia, USA, France, Canada, and China. A history of the ore industry is given with much data on the individual producer production, ore analysis, etc.—C.V.

ORES—MINING AND TREATMENT

Spain's largest iron mine doubles output (*Min. J.*, 1961, **256**, April 14, 406–407) The Marquerado mine, owned by the Cia. Andaluza de Mines, S.A., which produced approx. 500000 t in 1960 (about 9% of the total Spanish output of 6000000 t for the year) is described, with prticulars of location and communications for domestic marketing and export. Data are presented on six phases in excavating, with details of equipment and operations, and underground problems are also discussed.—S.H.-S.

Powering Sahara iron-ore project Hawker Siddeley Group (*Oil Eng. and Gas Tur.*, 1961, **28**, Feb., 358) Twelve oil-engined Mirrlees generating sets are being supplied to operate in Mauritania on the western edge of the Sahara. Their various functions are indicated and a brief description of the units is given.—C.V.

Beneficiation of domestic chrome ores L. H. Banning and W. A. Stickney (*AIMME, Proc. Elec. Furn. Conf.*, 1959, **17**, 157–170) The authors present data on the consumption and uses of chrome ores and concentrates, and review research on beneficiation procedures. A method of evaluating chromite concentrates for subsequent use is proposed.—G.F.

The use of red mud in the 'Duna' Iron and Steel Works, Hungary A. Borovszky (*Koh. Lapok*, 1961 **94**, Jan., 10–13) The properties of red mud, its use with lime in the sintering plant and the effect of high alumina content of slag on the metallurgical processes in the blast-furnace are described.—P.K.

Thermal behaviour of manganese minerals in controlled atmospheres W. M. Dressel and H. Kenworthy (*US Bur. Mines, Rep. Invest.* 5761, 1961, pp.35) Thermal analysis curves are presented for certain Mn minerals, viz. hausmanite, bixbyite, braunite, pyrolusite, lithiophorite, cryptomelane, hollandite, manganite, rhodochrosite, and rhodonite. The original minerals and the products of their thermal decomposition were identified by X-ray diffraction analysis, supplemented by chemical analysis and mineralogical identification. The reactions of the individual samples of each mineral were virtually the same whether heated in air, helium, or carbon dioxide. Results are tabulated (132 refs).—S.H.-S.

Chlorination of an Idaho ilmenite E. C. Perkins, H. Dolezal, and R. S. Lang (*US Bur. Mines Rep. Invest.* 5763, 1961, pp.16) The purpose of the research described in this report was to develop techniques for using ilmenite from domestic deposits for the production of $TiCl_4$. Bench scale continuous chlorination of an Idaho ilmenite containing 27·9%Ti and 35·6% iron yielded a crude chloride suitable for purification and for the production of Ti metal and pigment. Experimental procedures and results are described and summarized.

Investigation of the dead burning of ilmenite concentrates in a vortex chamber G. F. Strizhov and P. A. Myasnikov (*Stal'*, 1961, (4), 327–332) The design of the vortex chamber is shown and test results on a plant with a daily output of 5 t are reported. These show much higher efficiencies than do rotary tube kilns or static kilns, and fuel consumption is only 40–50% of that in these types.

Magnetic roasting of Kerch tobacco ore with removal of arsenic A. N. Pokhvisnev, F. M. Bazanov, E. F. Vegman, and Yu. S. Yusfin (*Stal'*, 1961, (4), 289–293) Studies are described on sintering methods by which over 75% of the As is removed during sinter formation. Recovery of iron is 85–88% containing <0·03%As. Structures before and after roasting were examined.

The production and use of ferrocoke M. Kepka (*Hutník*, 1961, **11**, (2), 74–77) [In Czech] It is shown that the fine-grained fractions obtained in iron ore sintering are best employed in the production of ferrocoke. The latter is suitable for charging into the blast-furnace.—P.F.

Crushing samples of Lorraine ore to sintering size M. Pasquet and L. Pevergne (*Centre Doc. Sider. Circ.*, 1960, **17**, (6), 1429–1466) [In French] The problems of crushing Lorraine ore for sintering are outlined. Observations made regarding granulometry and chemical composition in the production of fines are given and the results of preliminary tests are compared with those of industrial and of semi-industrial tests. The need for additional tests before production on an industrial scale can begin is emphasized.

Effect of particle size upon the green strength of iron oxide pellets R. P. Jewett, C. E. Wood, and J. P. Hansen (*US Bur. Mines Rep. Invest.* 5762, 1951, pp.15) The object of this investigation was to correlate the crushing strength of green pellets prepared from magnetite, specular, and earthy hematite with the particle size of these respective raw materials. The effect of particle size upon a number of fine ores and concentrates was studied, but no attempt was made to correlate the strength of fired pellets and particle size. The interdependence of strengths of green pellets and specific-surfaces of the iron ore concentrates from which they were made was shown. Pellets were also prepared from an iron ore containing colloidal materials. The strengths of these pellets were not linear with the specific surface, but increased rapidly at a specific surface near 30000 cm^2/cm^3. This indicates that the increased strength was probably due to the effect of the colloid on the porosity of the pellet.—S.H.-S.

Putting into operation machines for in-line burning of limestone at a sinter plant V. N. Krivosheev, V. A. Polstyanoi, G. I. Chernov, and V. S. Laznevoi (*Stal'*, 1961, (4), 293–296) Adding horizontally revolving grate lime kilns to the sinter line at Makeevka enables fresh lime to be fed uniformly to the sinter mix at 1000°C. Costs and savings are estimated and further improvements are suggested.

Production of self-fluxing sinter B. Mitka (*Koh. Lapok*, 1961, **84,** Jan., 19–22) The production and use of self-fluxing sinter at Nova Huta, Polen are described in the paper with special regard to the crushing of ores, limestone, and coke, the crushing machines employed, addition of lime to the mixtures, and to the dust control in the sintering plant. Finally, the effect of self-fluxing sinter on pig iron production in blast-furnaces is discussed.

Construction and design problems involved in a new sintering plant R. A. Slater (*Iron Steel Eng.*, 1960, **37,** Dec., 114–117) The plant described is the equipment installed at the Ohio plant of US Steel Corp.

Nodulized sinter raw-mixes S. Zielinski, A. Maslanka, and M. Kowalewski (*Hutnik*, 1961, **28,** (2), 44–49) A discussion of Tigerschold and Ilmeny's theory of nodulizing (*Proc. Blast. Furn. Comm.*, **9,** 1950, 18), is followed by the description of nodulizing. Best results obtained were on 3–6 mm size coated by coke breeze dust. As the permeability of nodulized beds is greater the depth of the bed must be increased up to 500 mm to prevent the air from passing too quickly through it.

Automatic control of the speed of a sinter machine I. P. Khudorozhkov, Yu. V. Simakov, G. S. Nesterov, and S. V. Basilevich (*Metallurg*, 1960, (12), 2–4) [In Russian] An automatic control based on the temp. difference between the two last windboxes is explained together with the electrical scheme.

Cost effects of the chemical qualities of sinter fuels. Part II J. Griffen (*Blast Furn. Steel Plant*, 1960, **48,** Dec., 1255–1261) Comparative values of various sinter fuels when anthracite no.5 of 14·41% dry ash at $10.0/NT as received is taken as a standard are tabulated and the factors affecting costs are discussed (10 refs).

The kinetics of indirect reduction H. Schenck and H.-P. Schulz (*Arch. Eisenh.*, 1960, **31,** Dec., 691–702) Diffusion of reducing gases through the pores in the ore to the location of the reaction, and the actual reaction, are viewed as rate-determining component stages in indirect reduction. Experiments are described on the reduction mechanism, and topics dealt with are the topochemical and quasi-topochemical behaviour of the ore as a whole, the topochemical behaviour of the single crystal in the ore sample, dependence of rate of reduction on the form and dimensions of the sample, the influence of cracking on reduction rate, the dependence of reduction rate on the CO content of the reducing rate, and the simultaneous reduction of several phases (18 refs).—

The influence of three foreign cations on the reduction of magnetite V. J. Moran and A. E. Jenkins (*JISI*, 1961, **199,** Sept., 26–33) [This issue].

FUEL—PREPARATION, PROPERTIES AND USES

The development of the production of coking coal in Hungary J. Schwertner (*Koh. Lapok*, 1961, **94,** Jan., 35–37) The development of coal mining in the Mecsek area, and the necessary reconstruction of the coal washing plant in order to increase the coking-coal output are described in the paper.—P.K.

Coke production economically in rotary hearth furnace Salem-Brosius Inc. (*Indust. Heat.*, 1960, **27,** Dec., 2608–2610) A continuous furnace being developed for making metallurgical coke will heat a deep coal bed in one revolution. Hot exhaust gases are piped to the ignition zone, and no outside heat is supplied. Final exhaust gases are collected for by-product recovery.—K.E.J.

Carbonizing tests with Tuscaloosa oven: factors influencing apparent specific gravity J. B. Gayle and W. H. Eddy (*US Bur. Mines Rep. Invest.* 5744, 1961, pp.18) A study of the difference in apparent specific gravities of experimental and commercial cokes confirmed the assumption that charge height is the principal variable involved. Analytical data for the various charges and the resultant cokes are appended. Further data are needed for actually defining an effective charge density.

Production of blast furnace coke from 75% blend of Illinois Coal Granite City Steel Co. (*Indust. Heat.*, 1960, **27,** Dec., 2615) A long period of trials has enabled successful coke to be made from 75% Illinois soft high-volatile coal and 25% West Virginia low-volatile coal (analyses given).—K.E.J.

Measurement and control of the coke supply V. Ya. Kozhukh and N. P. Onishchenko (*Metallurg*, 1960, (11), 10–11) [In Russian] Simple schemes for the automatic recording of the weight of the coke and of a general control of its supply are explained.

The use of microscopy in coke research K. Beneš and P. Dvořak (*Sborník* (Ostrava), 1960, **6,** (3–4), 439–501) The paper is virtually a treatise on the theory and practice of the microscopy of coke, and its relation to practical problems of the determination of the structures, compositions, and properties of lump coke and coke powders.—P.F.

Fuel-oil replacing coal at 'Labedy Steel Works' M. Godawa and W. Kirsz (*Hutnik*, 1961, **28,** (2), 56–62) The fuel oil used had a flash point of 180–220°C, a calorific value of 9800–10 200 kcal and a S content of 1·0–1·5%. Blending with tar oils led often to troubles because of carbon precipitation. The burner with an aperture of 27 mm burned 1 t/h using 800 m^3/h of air at 6 atm. The air was preheated to 130–200°C in recuperators by waste gas. The length of the flame was determined by the rate of combustion and the amount of the fuel burnt. The rate was 11 kg of fuel oil per ton of steel, the smelting time dropped from 9·18 to 8·38 h, the production rose from 8·9 to 9·47 t/h, the average amount of coal saved was 17 kg/t of steel.

The importance of furnace gas management in iron works O. Klöckl (*Met. Constr. Masini*, 1961, **13,** (1), 54–57) The exploitation of furnace gas is surveyed discussing the various losses—technological losses due to various construction and operation factors, distribution losses due to process factors in given installations, and losses due to lack of consumers. The importance of adequate management of the furnace gas, by suitable design of processes, operations, and construction is demonstrated.—M.L.

AIR POLLUTION AND SMOKE

Filtering air for steel mills C. D. Wright (*Iron Steel Eng.*, 1960, **37,** Dec., 155–163) Important points to be considered in choosing the type of filter for a specific air cleaning application are summarized. The characteristics of viscous impingement filters, strainer filters, and electrostatic precipitators are reviewed.

Fume control J. A. Glasgow (*AIMME, Proc. Elec. Furn. Conf.*, 1959, **17,** 387–388) Electrostatic precipitators are used for fume removal in the Cleveland plant of Jones and Laughlin Steel Corp. The author briefly describes the design and operation of the equipment.—G.F.

Bag house dust collecting E. Franzen (*AIMME Proc. Elec. Furn. Conf.*, 1959, **17,** 389–390) The Chicago plant of A. Finkl and Sons uses bag-filter dust collection in its electric furnace shop. Brief details are given of the design and operation of the equipment.—G.F.

Regarding suitable hygienic methods of cleaning the gases escaping from an O.H. furnace V. A. Gudemchuk, E. M. Shabunin, Yu. V. Krasovitzkii, and L. A. Barkina (*Metallurg*, 1960, (12), 21–23) [In Russian] Some purification units are explained with diagrams; they consist of a cyclone and dust collecting tube, of a glass wool filter and of an electrical dust precipitator, at the Hammer and Sickle Plant.

TEMPERATURE MEASUREMENT AND CONTROL

Thermocouple made at Texas Electric Steel Casting Company E. L. Kingham (*AIMME, Proc. Elec. Furn. Conf.*, 1959, **17,** 414–415) A brief description is given of an immersion pyrometer made and used at Texas Electric Steel Casting Co.—G.F.

Temperature measurement based on the viscous flow of gas in a Wheatstone-bridge network H. J. Hoge (*Rev. Sci. Inst.*, 1961, **32,** Jan., 1–6) A Wheatstone-bridge arrangement of capillary tubes carrying a flow of inert gas is described; in this the resistance to flow of a capillary served as a thermometer. The resistance is α to the product $T\mu$ for constant mass rates of flow in the viscous régime. Gas viscosity thermometers have relatively open linear scales and can be employed over a wide range of temp.; with He, this product varies strongly and smoothly at temp. from below 1–> 1500°K and probably much higher. Experimental tests with Al_2O_3 capillary thermometers in a high temp. furnace are reported and some of these thermometers were reasonably stable at 1788°K.

Tests and comparisons of carbon and germanium thermometers P. Lindenfeld (*Rev. Sci. Inst.*, 1961, **32,** Jan., 9–11) Two encapsulated Ge thermometers have been calibrated and tested between 1·4 and 4·2°K and within the precision of the instruments ($\pm$0·4 millidegree) no change in the calibration was found after cycling to room temp. or after temporary removal of the measuring apparatus; it was found that the Ge thermometer was considerably better than the C-type since the latter, encapsulated, underwent unpredictable change under identical circumstances.—C.V.

REFRACTORY MATERIALS

Properties of refractory materials: Collected data and references W. G. Bradshaw and C. O. Matthews (*PB* 171101, 2nd ed., 3rd printing, 1960, June, pp.114; *LMSD*–2466; from *US Res. Rep.*, 1961, **35,** Jan. 13, 69) A literature survey of materials melting at > 2500°F.

Electric-arc fusion-cast alumina refractories K. H. Sandmeyer and W. A. Miller (*AIMME, Proc. Elec. Furn. Conf.*, 1959, **17,** 257–266) The authors give a general description of the processes by which fusion-cast ceramics are produced. The various stages in the processes are given and are compared with those in electric arc production of steel.—G.F.

Phosphate bonded refractories for speciality applications G. J. Grott (*AIMME, Proc. Elec. Furn. Conf.*, 1959, **17,** 391–394) The author considers the use of phosphate-bonded refractories in applications calling for a smooth surface, resistant to penetration and wetting. He discusses a number of different materials and outlines the method of producing the refractory.—G.F.

Quality control of ladle refractories R. E. Hauser (*AIMME, Proc. Elec. Furn. Conf.*, 1959, **17,** 86–89) The author discusses the desirable qualities of ladle refractories and describes the testing methods used at Bethlehem Steel Co. for quality control purposes.

High-alumina castable refractories for ladles S. O. Smith (*AIMME, Proc. Elec. Furn. Conf.*, 1959, **17,** 396–403) The use of high-alumina castable ladle linings at Texas Foundries Inc. has reduced ladle costs, cut down heat losses, and reduced inclusion content of the steel. The author describes the lining procedure and gives details of costs, compared with a rammed magnesia lining.

IRON AND STEEL—GENERAL

Conference on the co-ordination of the most important researches on iron and steel during 1951 Yu. M. Shishkin (*Stal'*, 1961, (4), 382–383) A notice of the conference and the topics for discussion.

Industrial research in iron and steel works A. Michel (*Technische und Wissenschaftliche Berichte der August Thyssen-Hütte*, 1959, **1,** 15–17) A review of the ground covered by research in the iron and steel industry, with particular reference to the activities of August Thyssen-Hütte, given at the opening of the research department and laboratory of A.T.-H. in July 1959.

The electrochemical theory of smelting and related reactions: Technical report No.36 X. de Hemptinne (*AECV*–4504, 1959, Nov., pp.43; from *US Res. Rept.*, 1961, **35,** Jan. 13, 126) [No abstract].

Technical development in the iron and steel industry with special reference to the new plants of August Thyssen-Hütte AG A. Michel (*Technische und Wissenschaftliche Berichte der August Thyssen-Hütte*, 1959, **1,** 9–10) A brief review of developments in blast furnace, steelmaking, and rolling practice between 1937–57,

with a comparison of USA and German practice.

Jones & Laughlin Aliquippa Works (*Iron Steel Eng.*, 1960, **37**, Nov., JL1–JL64) Raw materials, iron and steelmaking (including the new basic oxygen furnace plant), rolling mills, tubemaking plant, rod and wire mill, tinning mill, metallurgical control, utilities, and service departments are dealt with.

BLAST-FURNACE PRACTICE AND PRODUCTION OF PIG IRON

The present state and future tasks of Hungarian blast furnace plants L. Czecze (*Koh. Lapok*, 1961, **94**, Jan., 1–5) The present state and future tasks in ore dressing and pig-iron production in Hungary are discussed in the paper. Crushing and screening of iron ores and limestone to less than 60 mm lump size, expansion of ore sintering, automatic steam injection into the blast, separate blast control in every tuyere, and higher blast temp. are the main proposals to increase the production of pig iron.—P.K.

The development of pig iron production since the Conference of the Hungarian Blast-Furnacemen in 1957 P. Pilter (*Koh Lapok.*, 1961, **94**, Jan., 14–18) The paper is an account of the fulfilment of resolutions passed at the Conference of the Hungarian blast-furnacemen at Balatonszéplak in 1957. Such resolutions were e.g. more use of Hungarian iron ores and ore substitutes (open-hearth slag, cinder, scale, etc.); beneficiation of manganese-carbonate ores; increase in the production and use of indigenous coke; higher blast temperature.

Iron ore reduction kinetics and thermodynamics. II W. A. Hockings (*Indust. Heat.*, 1960, **27m** Nov., 2406–2408) Details are given of the apparatus in which pure hematite was reduced to Fe by H_2. A rate equation is given which holds between 400° and 600°C without deviations.—K.E.J.

The reduction of the iron values of ilmenite to metallic iron at less than slagging temperatures R. H. Walsh, H. W. Hockin, D. R. Brandt, P. L. Dietz, and P. F. Girardot (*Trans. Met. Soc. AIME*, 1960, **218**, Dec., 994–1003) New Jersey, Florida, and Canadian ilmenites were reduced with hydrogen or coke under various experimental conditions and the phase changes occurring in the ilmenite upon reduction have been studied by microscopical examination of polished sections and by X-ray diffraction. The products formed were dependent upon the type of ilmenite, temp., time, and reducing agent. Of the reducing agents, hydrogen was the more effective at lower temp.

Developments in ironmaking and furnace design at Appleby-Frodingham, from an engineering aspect A. Bridge (*JISI*, 1961, **199**, Sept., 52–69) [This issue].

Erection of Tobata No.1 blast furnace (1500 ton/day) and its accessory equipments Yawata Iron and Steel Co. Ltd (*Ishikawajima Engng. Rev.*, 1960, April, 121–126; from *Japan Sci. Rev. Mech. Elect. Engr.*, 1960, **7**, Aug., 276) [No abstract].—C.F.C.

Experimental blast furnace being built to study reduction processes (*Indust. Heat.*, 1960, **27**, Dec., 2602) The furnace of US Steel Corp. will have hearth dia. 4 ft, working height 19 ft 6in, max. top pressure 50 lb, and blast heated to 2500°F max. It will have automatic probes, an infra-red gas analyser, and automatic stock weighing.—K.E.J.

New monolithic materials developed for maintaining blast furnace linings Harbison Walker Refractories Co. (*Indust. Heat.*, 1960, **27**, 2641–2644) Life of B.F.s between relinings can be prolonged by patching with monolithic refractories—high-Al_2O_3 castable in the hearth, the same or super-duty gun clay in the bosh, and low-Fe extra-strength castable in the stack.—K.E.J.

Amorphous carbon blocks and their use in blast furnace linings J. Bilaine (*Centre Doc. Sider. Circ.*, 1960, **17**, (6), 1467–1472) [In French] Amorphous carbon electrodes made from raw materials selected and treated at high temp. are obtained by carefully measured extrusion of mixtures. These blocks in sizes up to 750 × 500 mm and 4 m lengths are then heated in a reducing atmosphere are used for the carbon lining of blast furnaces. This article describes their characteristics and lining technique.

Note on carbon hearths at the Société Metallurgique de Normandie P. Chenet and P. Jourde (*Centre Doc. Sider. Circ.*, 1960, **17**, (6), 1473–1482) [In French] From an examination of hearths constructed by the carbon method and used it is concluded that the presence of a well-adjusted carbon ring in the hearth oven in difficult situations stops the pig iron reacting with the metal casing and that this carbon ring by its cooling effect prevents deep pig iron penetration. Also, that under such conditions the base of an existing defect is neither deepened nor widened.

Blast furnace bells and hoppers restored R. C. Mahon Co. (*Indust. Heat.*, 1960, **27**, Dec., 2602) The parts in Mn steel are rough machined with a 24 ft boring mill, hard-surfaced, and finish machined to 8 μin.—K.E.J.

Blast furnace charge distributer V. P. Tarasov (*Stal'*, 1961, (4), 303) A double cone design, the lower revolving, is shown.

Experience gained with a large blast furnace M. Ya. Ostroukhov, V. I. Kholzakov, and Yu. A. Popov (*Metallurg*, 1960, (12), 4–9) [In Russian] The history of a large blast-furnace at the Chelyabinsk Metallurgical Works in commission since Oct. 1958. For the first few months the burden was not uniform and consisted of five to seven components of varying origins. The burden was made more uniform later and the operation and maintenance work is described.

Smelting unfired iron ore pellets in an experimental blast furnace N. B. Melcher and M. B. Royer (*Blast Furn. Steel Plant*, 1960, **48**, Dec., 1265–1270) A description is given of preliminary experiments by the Federal Bureau of Mines on the practicability of adding raw pellets of taconite concentrate to blast-furnace feeds. It was shown that these pellets could be used successfully with no significant change in coke consumption and only a moderate increase in dust losses.

Dry charging at Hagondange J. de Miscault (*Centre Doc. Sider. Circ.*, 1960, **17**, (6), 1417–1423) [In French] Drying methods and equipment are described. The results of blast-furnace trials lasting four months using dried and humid materials are compared.

Operation of the blast furnace on fluxed sinter made from ores of the Tagil'-Kushvinsk region V. V. Frolov, B. L. Lazarev, L. Ya. Gavrilyuk, and A. A. Fofanov (*Stal'*, 1961, (4), 296–299) An account of the relining of the furnaces, experience in their operation, and present practice. Changes made from time to time are followed and possible improvements are noted.

Analysis of the operating conditions of the spherical hearth pad of a blast furnace E. M. Gol'dfarb (*Stal'*, 1961, (4), 299–302) Heat loss conditions for a carbon block pad are evaluated and depth of iron penetration is calculated. Stresses produced in the pad are then worked out and constructional details for minimizing the number and widths of cracks in the pad are suggested.

Arrangement for measuring temperatures at the walls of the stack Yu. G. Yaroshenko, B. L. Lazarev, and Yu. N. Ovchinnikov (*Metallurg*, 1960, (11), 11–13) [In Russian] A special instrument is explained which is capable of continuously measuring the temp. at the stack walls within the range of 600–1300° for long periods. The apparatus is efficiently protected within this temp. range and the scheme has very little lag.

Some aspects of predicting blast-furnace behaviour A. L. Hodge (*JISI*, 1961, **199**, Sept., 6–15) [This issue].

The use of natural gas in blast furnaces G. I. Adarjukov (*Koh .Lapok.*, 1961, **94**, Jan., 6–9) After reviewing the relevant literature, the author describes the enrichment of blast with natural gas and oxygen in the blast-furnaces of the southern region of the USSR, also commenting on the lower coke rate and higher production achieved, as well as on the plans for future development.—P.K.

Utilization of crude oil and methane gas in blast furnaces C. Avram (*Met. Constr. Masini*, 1961, **13**, (1), 1–9) The effects of the use of crude oil and CH_4 in blast-furnaces was studied. It was determined that preheating of the air is required and at an air temp. of 700°C the use of CH_4 has decreased coke consumption by 102 kg/t cast iron, no increase in H_2 content being observed in the cast iron. The use of crude oil results in lower output increase than when CH_4 is used but the reduction in cost is the same.—M.L.

Centralized control promotes flexibility in split-wind systems for blast furnaces US Steel Corp. (*Indust. Heat.*, 1960, **27**, Oct., 2108–2110) Details are given of the control panel and instruments used at Gary Works to link three turbo-blowers to four B.F.s, the fourth blower being on standby.—K.E.J.

Instrumentation and automatic control of blast furnace at Tobata Plant of Yawata Works, Yawata Iron & Steel Co. Ltd S. Hayashibe (*Fuji Elec. J.*, 1960, **33**, March, 249–256; from *Japan Sci. Rev. Mech. Elect. Engr.*, 1960, **7**, Aug., 276) [No abstract]—C.F.C.

Operational experiences with a steel tube blast heater H. Reinfeld (*Second Recuperator Conference Schack system*, Paris, 24–25 April, 1959, 43–47, VI I, Appendix 16–20) Several examples of the use of steel tube blast heaters for the blast furnace are given, and a more detailed account is given of the blast heater installed by Rekuperator K.-G., Düsseldorf, for the low-shaft furnace at the Klöckner-Mannstadt Works at Troisdorf.

A high-temperature Cowper stove D. Petit (*JISI*, 1961, **199**, Sept., 33–46) [This issue].

The mechanization and automation of the blast furnace section L. Ya. Shparber (*Metallurg*, 1960, (11), 6–9) [In Russian] The blast-furnaces at the Magnitogorsk Combine operate with two or three components in the charge consisting on an average of 93·4% self-fluxing sinter, 6·6% ore, and coke, and (per ton of iron) 1 kg limestone, 2 kg Mn ore, 12 kg foundry iron. There is no ore yard and an automatic scheme for charging the skips and the furnace and for supplying the coke is explained. The supply of steam, the preparation of the ore, the air heaters, and the melting process are also mechanized.

Controlling oxygen and moisture to a blast furnace J. L. Wallace (*Iron Steel Eng.*, 1960, **37**, Nov., 114–120) The effects of moisture changes on blast-furnace control are outlined, and the O_2 and moisture control system in use at Weirton Steel Co. is described.

Integrated hot blast stove/gas turbine cycles C. Rounthwaite (*JISI*, 1961, **199**, Sept., 47–51) [This issue].

Contaminating elements in pig iron L. Éles (*Koh. Lapok*, 1961, **94**, Feb., 75–80) The origin of contaminating elements in pig iron, such as As, Ti, Cu, Zn, Cr, V etc.; some methods for their elimination; their effect on cast iron and on hot and cold working and the mechanical properties of the steel are discussed.—P.K.

Some factors affecting pig-iron production and coke rate in blast furnaces A. Nahoczky (*Koh. Lapok.*, 1961, **94**, Jan., 38–43) The effect of blast enrichment with steam, methane, or fuel-oil residue, and of increased blast temp. on the pig-iron production and coke rate are discussed in the paper.—P.K.

Cowper stoves with higher blast temperatures by preheating the combustion air D. Petit (*Second Recuperator Conference* (*Schack system*), Paris, 24–25 April, 1959, 49–53, VII 1, Appendix 21–23) It is pointed out that in modern blast-furnace practice a high blast temp. must be obtained with gases of lower calorific value, and the Cowper stoves must be able to supply blast-furnaces with increasing dimensions. Factors in the design of modern Cowper stoves designed to meet these needs are reviewed.

Lining and operation of hot-metal mixers A. Latour (*Trans. Brit. Ceram. Soc.*, 1960, **59**, Oct., 432–435) Current practice with hot metal mixers at Völklingen is described and details of lining, expansion joints, life of mixer linings, heating schedules, etc., are supplied. An informative discussion is included.—C.V.

Casting of pig iron in casting machines K. R. Arenbeck (*Koh. Lapok*, 1961, **94**, Jan., 29–34) The author describes the construction and use of casting machines in the blast-furnace plant at Stalinstadt, East Germany, and discusses various factors affecting the

surface and structure of the pig iron produced, such as temp., cooling rate, slag content, preparation of moulds, etc.—P.K.

Technology of Dwight-Lloyd McWane ironmaking T. E. Ban and B. W. Worthington (*J. Met.*, 1960, **12,** Dec., 937–939) A summary of a paper presented at the autumn meeting of the Met. Society of ZIME, dealing with the production of iron by the D–LM (Dwight–Lloyd McWane) process by smelting hot, carbonized pellets produced as highly beneficiated feed in a conventional submerged-arc furnace (12 refs).

Recent developments in Strategic-Udy smelting processes M. C. Udy (*AIMME, Proc. Elec. Furn. Conf.*, 1959, **17,** 301–314) The author briefly outlines the principles of the Strategic-Udy smelting processes, emphasizing the chemistry and mechanics. Recent developments are described and potential applications are given.—G.F.

PROPERTIES, TREATMENT, AND USE OF SLAGS

Physical properties and constitution of liquid slags B. T. Bradbury and D. J. Williams (*Metallurgia*, 1960, **62,** Dec., 235–240) The main properties of simple silicate slag systems are discussed, with particular reference to recent work (21 refs).

The utilization of blast furnace slag M. Valko (*Koh. Lapok*, 1961, **94,** Jan., 23–28) The author describes the processing and utilization of blast-furnace slag in Hungary and abroad, and discusses the tasks for the period of the second Hungarian five-year plan.—P.K.

PRODUCTION OF STEEL

Preparation of scrap for remelting E. M. Guzev (*Stal'*, 1961, (4), 375–382) Present scrap treatment is reviewed and the development and supply of better equipment such as presses and shears are urged.

The Energy Centre at Tobata Plant of Yawata Works, Yawata Iron & Steel Co. Ltd T. Suzuki (*Fuji Elect. J.*, 1960, **33,** March, 260–266; from *Japan Sci. Rev. Mech. Elect. Engr.*, 1960, **7,** Aug., 276) [No abstract].

J & L installs computers on steelmaking and annealing units (*Iron Steel Eng.*, 1960, **37,** Dec., 185–186, 188) The use of an analogue computer for calculating charges for the basic open-hearth furnace, and the digital control computer system installed for controlling the annealing process are described.

Molten metal for converter made in the cupola J. Gibinski and J. Tucholka (*Prz. Odlew.*, 1961, **11,** (3), 73–81) The cooling of the cupola should be external, the optimum rate of the blast being 15 to 70 m/sec. Acid lining prevents desulphurization, and basic lining being too brittle, carbon lining was used. Yet the main factor in S-elimination was the VR of the slag (72–5). Cold blast resulted in scab formation and so the use of hot blast is recommended. With 40% of haematite pig iron the coke rate was 26%, limestone 15 to 35%, fluorspar 15%, the amount of blast 100–145 m^3/min; any S above 0·1% being removed outside the furnace.

Dry air as a substitute for oxygen in the blowing of stainless steel J. R. Bridges (*AIMME, Proc. Elec. Furn. Conf.*, 1959, **17,** 370–375) Dry air is used in place of oxygen during the blowing of stainless heats at Cameron Steel Works. The author describes the procedure and presents typical operating data. Tap-to-tap time is reduced, Cr recovery increased, and steel cleanness and physical properties are improved.—G.F.

Investigation of Bessemer converter smoke control A. R. Orban, J. D. Hummell, and R. B. Engdahl (*Trans. Met. Soc. AIME*, 1960, **218,** Dec., 1039–1049) The initial phase of a research programme on smoke abatement from Bessemer converters is described, using a 300-lb experimental converter and a 30-t commercial vessel. The addition of H_2 to the blast gas of the laboratory converter caused a marked decrease in smoke density. Smoke was also reduced when methane or ammonia was added instead of hydrogen. Against the use of hydrogen and methane the risk of explosion is hazardous for commercial practice, while ammonia is both toxic and costly to a prohibitive degree as a smoke suppressant. The research, which is sponsored by the American Iron and Steel Institute, continues.—S.H.-S.

Contribution to the mechanics and metallurgy of the blowing process T. Kootz (*Technische und Wissenschaftliche Berichte der August Thyssen-Hütte*, 1959, **1,** 105–109) The reaction mechanisms in the bottom and top-blown converter processes are considered and compared with those of the open-hearth process and the Rotor process (23 refs).

Instrumentation and automatic control of converter at Tobata Plant of Yawata Works, Yawata Iron & Steel Co. Ltd H. Ezaki (*Fuji Elec. J.*, 1960, **33,** March, 257–259; from *Japan Sci. Rev. Mech. Elect. Engr.*, 1960, **7,** Aug., 276) [No abstract].—C.F.C.

Recollections of the reconstruction of the Thomas steel plant W. Köhler (*Technische und Wissenschaftliche Berichte der August Thyssen-Hütte*, 1959, **1,** 47–48) A note on the six 40-t converter plant installed at the August Thyssen-Hütte works.

Increasing labour productivity in the OH furnace P. G. Goncharov (*Metallurg*, 1960, (12), 18–20) [In Russian] Some details of reorganizations undertaken at the Makeev Metallurgical Works which resulted in an increase of 6·6% in labour productivity.

Heat insulation of OH furnace roofs A. P. Klyucherov and S. N. Kondrat'ev (*Metallurg*, 1960, (11), 14–17) [In Russian] The construction of these roofs at the Nizhne Tagil' works is described. They are heat-insulated by resting on layers of lightweight chamotte (125 mm thick, in the semi-viscous state). Operating the furnace with heat-insulated roofs is more efficient and more economical than with the non-insulated roofs.

Fettling the new hearths of the large OH furnaces D. I. Deineko, M. G. Nechkin, and K. S. Nazarov (*Metallurg*, 1960, (11), 20–23) [In Russian] Experiments with four hearths at the Magnitogorsk Metallurgical Combine, in fettling with thick layers of refractory material have shown that the duration of the operation can be reduced by a factor of 3–4 without loss of quality. The first and last layers are composed of pure magnesite powder and the intermediary one consists of a mixture of magnesite powder, scale, and OH slags roasted with dolomite.

Slurry-mix, mixer and gun combination developed for hot patching of basic open hearth furnaces Harbison-Walker Refractories Co. (*Indust. Heat.*, 1960, **27,** Nov., 2461–2462) The mix is a fine-ground refractory material made with both chrome and chrome-magnesite bases, which have fast-setting, high-strength bonds. The gun is operated by air at 80 lb/in², and applies 1 500 lb of slurry in 10 min.

Steelmaking experience with pig iron of low manganese content G. Répási (*Koh. Lapok*, 1961, **94,** Feb., 72–74) A decrease in Mn content from 2–3% to 0·8–1·2% in hot metal neither worsened the quality of the steel produced, nor increased the consumption of deoxidants or the cost of steel production. However, desulphurization of the hot metal is desirable to ensure low (<0·030%) sulphur content if such a limit is required.—P.K.

The use of a lime–iron oxide sinter in the basic open hearth process W. Fiedler (*Freiberger Forschungshefte, Eisenhuttenwesen*, 1960, (B43), pp.64) After reviewing the literature dealing with the use of sinter and compacts in OH practice, the author's experiments with CaO–iron oxide sinter are described, together with the results of comparative trials with normal operation. A fluid, reactive slag was obtained more quickly using the sinter, production was increased, and very efficient dephosphorization was achieved; MgO content of the slag up to the stage of the 1st sample can be kept lower. The oxidizing power of the sinter for C is less than that of an equivalent amount of O_2 added as ore or mill scale (46 refs).

Evaporation cooling of the OH furnace operating at increased pressure A. M. Svistunov and D. Ya. Feiderov (*Metallurg*, 1960, (12), 17–18) In June 1960, the first fuel oil fired OH furnace in Russia with vaporization cooling was commissioned at the Ishev Metallurgical works. The vapour pressure in the separation tank is 12 atm. On the basis of the first results it can be stated that the cooling of the various units is ensured satisfactorily by means of drop forged and welded structures and that the savings on this head for this one furnace alone will exceed 500 000 roubles yearly.

The service life of refractory linings with oxygen and compressed air in the blast M. M. Dvorkin, G. Kh. Ickhakov, N. S. Redin, Zh. A. Vydrina, and T. N. Bushueva (*Metallurg*, 1960, (12), 15–17) [In Russian] To strengthen the linings of OH furnaces operating under these conditions the cooling of the furnace roof should not be allowed to fall below 1450–1 500°; charging of cooling materials during the changeover of the valves should be avoided, the time for reversing should be curtailed as much as possible and the temp. drop should not exceed 70–100°/min, also the supply of oxygen and compressed air should be so adjusted as to ensure full combustion.

Infiltrated air and heat losses in a 60 t fixed open-hearth M. Michalowski (*Prac. Inst. Hut.*, 1960, **12,** (6), 273–287) Leaky linings and valves result in air infiltrating into the conduits the amount of which can be calculated from the chemical composition of the flue gas and the composition and the calorific value of producer gas and the air required for combustion. Using a formula the amount of air leaking into the air conduits was calculated as 3200 m^3/h and that into the gas conduit as 1 000 m^3/h.

Conclusions from experience with the use of oxygen and compressed air in the open-hearth process A. N. Khudyakov and V. S. Krivonosov (*Stal'*, 1961, (4), 371) A brief note from the Urals Institute for Ferrous Metallurgy, 70–75 m^3/t of compressed air raised output 10–11%. Enrichment with 30–35 m^3/t of O_2 raised output 12–15% with 14–20% reduction in fuel consumption.

Fuel oil injection at Margam K. C. Sharp (*JISI*, 1961, **199,** Sept., 69–75) [This issue].

Experience with open hearth furnaces fired by natural gas on the self-carburization process A. I. Zhukov, M. M. Zhil'ko, N. P. Merschii, M. S. Shklyar and L. G. Slez (*Stal'*, 1961, (4), 307–311) Improvements are shown by a changeover to cold natural gas from mixed coke-oven and blast-furnace gases. The best conditions, including minimum effective oxygen feed, are indicated.

The operation of a recirculation recuperative steelmaking furnace M. A. Glinkov and G. I. Demin (*Stal'*, 1961, (4), 317–318) A reply to criticism (*ibid*,. 1959, (10)) of an article previously published (*ibid.*, 1959, (1)).

Some aspects of recuperator design in the USA T. E. Dixon and H. A. Kühne (*Second recuperator Conference* (*Schack system*), Paris, 24–25 April, 55–59, VIII 1–2, appendix 24–28) Special factors existing in USA are pointed out—inexpensive fuels with high calorific values, high labour costs, and a highly competitive furnace building industry; and some details of experience in the USA are given.

18th Annual Electric Furnace Program (*J. Met.*, 1960, **12,** Dec., 920–924) A programme of the Conference held at Chicago, 30 Nov.–2 Dec., sponsored by the Electric Furnace Committee of the Iron and Steel Division of the Metallurgical Society of the American Institute of Mining, Metallurgical, and Petroleum Engineers.

A change from open hearth to arc electric furnaces W. J. Bolton (*Indust. Heat.*, 1960, **27,** Dec., 2589–2600) Details are given of the change from five 50-t OH furnaces to two 100-t electric furnaces, with auxiliary services, at Bethlehem Steel Co'.s Seattle plant. A phased programme enabled full production to be maintained for all but a few weeks.—K.E.J.

Model relationships in electric smelting furnaces J. A. Persson (*AIMME, Proc. Elec. Furn. Conf.*, 1959, **17,** 423–426) The author reviews previous work using dimensional analysis and model theory, to illustrate how furnace electrical requirements and efficiencies can be determined for a variety of smelting processes.

High-alumina roofs for electric arc furnaces R. Wood (*AIMME, Proc. Elec. Furn. Conf.*, 1959, **17,** 69–70) Arc furnaces at Sheffield Division of Armco Steel Corp. produce mostly plain carbon steel. Interim results are given of

trials with 70% alumina brick in place of silica in the roofs.—G.F.

Use of high-alumina roofs H. M. Parker (*AIMME Proc. Elect. Furn. Conf.*, 1959, **17**, 70) The arc furnace at Butler plant of Armco Steel Corp. is used for stainless steel. The use of 70% alumina roof brick in place of silica has resulted in a 37% saving in roof costs.—G.F.

Castable refractories in electric-arc furnace roofs—Progress report J. D. McCullough (*AIMME, Proc. Elec. Furn. Conf.*, 1959, **17**, 72–80) The author surveys recent experience with castable refractories in arc furnace roofs. Such refractories offer 20–40% reduction in installation time when used for the centre sections, and have proved beneficial in hot spots and skewbacks.—G.F.

Castable electrode rings R. J. Schiebel (*AIMME, Proc. Elec. Furn. Conf.*, 1959, **17**, 64) The author discusses unsuccessful attempts to produce non-water-cooled electrode rings from castable refractories.—G.F.

Electrode roof cooler rings L. G. Cotton and P. G. Fairchok (*AIMME, Proc. Elec. Furn. Conf.*, 1959, **17**, 61–63; *Ind. Heat.*, 1960, **27**, Nov., 2454–2458) The authors describe attempts to develop electrode cooler rings suitable for use with high-alumina arc furnace roofs. The most suitable seems to be an outer water-cooled steel ring with an inner refractory ring to act as an electrical insulator.—G.F.

Service life of silica and high-alumina brick in electric furnace roofs J. M. Murphy (*AIMME, Proc. Elec. Furn. Conf.*, 1959, **17**, 67–69) Trials in the Duquesne Works of US Steel Corp. on an intermittently operated furnace show that 70% alumina brick gives four times the roof life of silica brick, at 2·6 times the cost.—G.F.

Recent European developments in consumable electrode melting W. J. Childs (*AIMME, Proc. Elec. Furn. Conf.*, 1959, **17**, 7–16) The author briefly describes the position of consumable electrode melting in Europe, and discusses the design and operation of the Heraeus unit at ICI Ltd, Birmingham. Research into segregation and pool depth is outlined.—G.F.

Electrical behaviour of consumable electrode arcs in variable pressure systems T. E. Butler and R. P. Morgan (*AIMME, Proc. Elec. Furn. Conf.*, 1959, **17**, 17–26) As an aid to the development of improved control techniques, the authors have established a relationship between the occurrence of specific reduced-pressure arc modes and changes in the instantaneous characteristics of the voltage signal.

Consumable electrode melting of steel and high-temperature alloys R. C. Buehl and A. M. Aksoy (*AIMME, Proc. Elec. Furn. Conf.*, 1959, **17**, 51–57) The authors discuss the advantages in centre porosity, gas content, cleanness, and segregation of consumable-electrode steel compared with conventional material. Important features and trends in the design of equipment and operating procedures are reviewed.—G.F.

Determination of electrode position and its significance M. J. Geigal (*AIMME, Proc. Elec. Furn. Conf.*, 1959, **17**, 430–433) The author describes the methods of recording and controlling the electrode position in the submerged-arc furnaces at Chromium Mining and Smelting Corp. The procedures permit the use of relatively constant charge mixes and standard operating procedures.—G.F.

Determination and control of electrode penetration W. R. Meredith, A. D. Gate, and H. R. Tuten (*AIMME, Proc. Elec. Furn. Conf.*, 1959, **17**, 435–437) The authors describe a simple and reliable system which has been developed at the Beverley plant Interlake Iron Corp. for the determination and control of electrode penetration in submerged-arc furnaces.—G.F.

Electrode penetration in submerged-arc furnaces A. M. Kuhlmann (*AIMME, Proc. Elec. Furn. Conf.*, 1959, **17**, 438–439) The author discusses the importance of electrode penetration in maintaining maximum efficiency in submerged-arc furnace operation, and also considers its effect on the quality of the product.—G.F.

Determination of electrode position and its significance R. N. McClure (*AIMME, Proc. Elec. Furn. Conf.*, 1959, **17**, 439–441) The author discusses the effects of electrode penetration on the operating conditions of submerged-arc furnaces. Means of determining and controlling electrode position are reviewed.

Auxiliary meltdown torch V. J. Howard (*AIMME, Proc. Elec. Furn. Conf.*, 1959, **17**, 419–420) The auxiliary melt-down burner used on the 2-t acid arc furnace at Oklahoma Steel Castings Co. is illustrated. Use of the burner has resulted in a 20 lb/min increase in melting rate and a 50 kWh/t decrease in electricity consumption.—G.F.

Use of oxygen-fuel gas burners for scrap meltdown in electric furnaces G. W. Hinds and A. L. Hodge (*AIMME, Proc. Elec. Furn. Conf.*, 1959, **17**, 290–298) A description is given of a simple and practical process for using oxygen-fuel burners to supplement electric power input in arc furnaces. Production tests show more uniform melting rates, and a production increase and power consumption decrease of 15–20%.—G.F.

Effect of melt-shop practice on cleanliness for high-speed steels W. L. Havekotte (*AIMME, Proc. Elec. Furn. Conf.*, 1959, **17**, 316–326) Macro-cleanliness of high-speed steels at Firth Sterling Inc. was materially improved during a long-term investigation. This is felt to be due to improved slag and temp. control, cleanness of ladles and moulds, improved alloy addition procedure, and prevention of slag entering the ladle.—G.F.

Melting practice to produce extra low-sulphur carbon steel A. J. Kiesler (*AIMME, Proc. Elec. Furn. Conf.*, 1959, **17**, 148–150) The author outlines a procedure developed by the general Electric Research Laboratory for producing very low-sulphur steels. The practice is based on sulphur removal under a basic reducing slag before oxygen lancing.—G.F.

Transductor electrode control for arc furnaces W. Gruber (*AEG Prog.*, 1960, (1), 97–105) Transductor controllers used in conjunction with induction motors, reversing clutches, and amplidyne generators in the automatic control of arc-furnace electrodes are described.—C.V.

Joint effect of sulphur and rare-earth metals on mechanical properties of cast complex low-alloy electric furnace steel R. D. Engquist (*AIMME, Proc. Elec. Furn. Conf.*, 1959, **17**, 125–144) The author gives details from a series of 18 high-frequency furnace heats of low-alloy steel, half of which were treated with rare-earth additions. The sulphur contents ranged from 0·005% to 0·045%. The variations in mechanical properties are analysed statistically and correlated with the sulphur content and rare earth addition.

Jet tapping for electric furnaces H. L. Schaaf jun. (*AIMME, Proc. Elec. Furn. Conf.*, 1959, **17**, 345–351) The author describes the use of 'jet tappers' in electric furnace practice and discusses their characteristics. The advantages of the practice over normal opentaphole procedure are outlined.—G.F.

Correlation between tap temperatures, ladle temperatures, and pouring stream temperatures W. H. Burr and H. Green (*AIMME, Proc. Elec. Furn. Conf.*, 1959, **17**, 283–288) An experimental programme is in progress at Duquesne Works of US Steel Corp. to determine the pattern of temp. losses during tapping and teeming of electric furnace heats and the correlation, if any, between metal temp. and steel quality. The equipment and techniques used are described and preliminary data obtained are presented.—G.F.

Electric Furnace precipitator J. L. Venturini (*AIMME, Proc. Elec. Furn. Conf.*, 1959, **17**, 378–385) The author describes the way in which Bethlehem Pacific Coast Steel Corp. has tackled the problem of fume removal in its Los Angeles electric furnace shop. The particular nature of the fume is discussed, and details are given of the design and operation of the electrostatic precipitator installed in the shop.

Some particular aspects of the problem concerning the cleaning of the fumes of electric-arc furnaces L. G. Septier and P. J. Leroy (*AIMME, Proc. Elec. Furn. Conf.*, 1959, **17**, 385–386) The authors describe briefly how the characteristics of fume vary during different stages of a heat, and outline the methods of fume removal.—G.F.

Monitoring a demand meter with television J. M. Hathaway (*AIMME, Proc. Elec. Furn. Conf.*, 1959, **17**, 415–418) At Massillon Steel Casting Co., television is used to monitor to the furnace location a remotely-placed demand meter, and has resulted in lower monthly demand figures. A description of the circuit is given.—G.F.

Special additives in stainless and alloy steels S. J. Myford (*AIMME, Proc. Elec. Furn. Conf.*, 1959, **17**, 355) A brief account is given of the effects of additions of Li metal in deoxidizing, flushing hydrogen, and reducing non-metallic inclusion content in steel.—G.F.

Effect of various deoxidizers on cast steel C. E. Sims and C. W. Briggs (*AIMME, Proc. Elec. Furn. Conf.*, 1959, **17**, 104–122) The authors discuss the theory of deoxidation of steel, with special reference to the $C-O_2$ and H_2-O_2 reactions which are responsible for porosity in castings. The characteristics of deoxidation by Si, Mn, Al, Ti, Zr, misch metal, Se, Ca, Mg, Na, Ba, K, and Li are described, and their effects on the form of sulphide and nitride inclusions are also noted.

Mechanization of the deoxidizer additions to the teeming ladle. Information bulletin of the Central Office of Technical Information of the Stalin Council for National Economy (*Metallurg*, 1960, (11), 23) [In Russian] An assembly evolved at the Enakiev Metal Works is described, consisting of a crusher, fed directly from the store yard, a bunker, crane, automatic scale, and monorail conveyor. Its operation, it is claimed, has resulted in substantial economies.

Rare earth alloy and lithium as additives to steel A. J. Nimeth (*AIMME, Proc. Elec. Furn. Conf.*, 1959, **19**, 353–354) At the Jones & Laughlin Steel Corporation's Detroit works, rare-earth additions have reduced conversion and conditioning costs on stainless free-machining grades. Li additions, combined with argon flushing are used when a heat appears wild or gassy.—G.F.

The production of ingot moulds in Czechoslovakia R. Kudrna (*Slévárenství*, 1961, **9**, (2) 49–52) [In Czech] As a preliminary to the early planned expansion of the production of ingot moulds, methods of casting them in various countries are surveyed. Recommendations are drawn up as a result of the study.—P.F.

Temperature distribution in steelworks ingot moulds F. Havlíček (*Sborník (Ostrava)*, 1960, (5–6), 567–577; (7), 729–747) [In Czech] The determination of the temp. distribution in ingot moulds after pouring is discussed with reference to the author's work designed to devise methods suitable for the prevention of premature withdrawal of ingot moulds from service for reconditioning.—P.F.

The displacement of the ladles when teeming with one spout L. Ya. Shparber and A. I. Dorman (*Metallurg*, 1960, (12), 10–11) [In Russian] An installation is described consisting of a reversible windlass which can move a 585 t ladle (the pulling force required is 6500 kg) and successively position the four ladles under the spout for filling with hot iron at the MMK.

Developments in the continuous casting of carbon steel at the Novo Lipetsk Iron and Steel Plant V. S. Rutes, B. N. Katomin, Yu. E. Kan, V. K. Petrov, and V. V. Lobanov (*Stal'*, 1961, (4), 311–317) The machine is described and illustrated and operational experience is reported. The advantages of large units and the metal savings compared with conventional ingot casting are stressed. It is considered that units much larger than these 90 t machines could be constructed with advantage.

Development of a process for the continuous casting of killed carbon steel into 130 × 620 mm cross section slabs at NTMZ N. M. Lapotyshkin (*Stal'*, 1961, (4), 321) A note from TsNIIChM. Studies aimed at the prevention of external cracks on the broad faces are briefly reviewed. An asymmetrical teeming method was found satisfactory.

Continuous casting of rimming steel in a 200 × 200 mm cross setion mould N. M. Lapotyshkin (*Stal'*, 1961, (4), 321) A note from TsNIIChM in conjunction with the Ukraine Research Institute and Ural Research Institute for Ferrous Metals. Satisfactory methods have been

worked out at Novo-Tula, also the deoxidation and continuous casting of semi-killed steel. Successful rolling is reported.

Development of a process for the continuous casting of transformer steel into 130 × 620 mm slabs N. M. Lapotyshkin (*Stal'*, 1961, (4), 321) A note from TsNIIChM in conjunction with the Ural Research Institute for Ferrous Metals. The optimum conditions are very briefly indicated.

Continuous casting of rimming steel for production of rolled rod on a plant of the Urals Institute for Ferrous Metallurgy P. V. Fadeev (*Stal'*, 1960, (4), 383) A note on the successful casting of 10 heats and its rolling to rod, wire, pins, and screws.

Development of radioactive gauges for the automation of continuous casting N. M. Lapotyshkin (*Stal'*, 1961, (4), 321) A note from TsNIIChM. The device (type URU–6) is not described but is said to be satisfactory in operation.

Investigation of the features of the crystallization, structure, and quality of continuously cast steel N. M. Lapotyshkin (*Stal'*, 1961, (4) 321) A note from TsNIIChM. Porosity is slightly worse than in ingots teemed with feeder heads but slightly better than in those teemed without. Quality of rolled metal is, if anything, higher. Mean rate of crystallization is higher and less dendritic segregation occurs.

The quality of tinplate steel poured into jar moulds J. Teindl and B. Otta (*Sborník (Ostrava)*, 1960, **6**, (7), 749–758) [In Czech] A comparison is made of the resistance to cracking on pressing of rimming steels cast either into open moulds or into jar moulds. The author's results, and evidence from the literature, support the view that despite certain drawbacks, jar moulds give better steels, mainly because of greater structural homogeneity. In the detailed discussion of the results, special attention is given to the role of phosphorus as a determinant of quality.

On the causes of the bulging of ingots and slabs I. P. Zabaluev and E. I. Moshkevich (*Stal'*, 1961, (3), 249–251) This is a discussion arising from an article by Chirkin and Ksemzuk (*ibid.*, 1960, (1)) of defects occurring generally near the head of the ingot in the form of porosity or cavities. It is observed in killed and alloy steels as well as in rimming steels. It is now attributed to the effects of gases diffused into cavities in the metal from the soaking pit atmosphere.

The nature of defects in steel ingots produced by the electro-slag process Yu. A. Shul'te, I. A. Garevskikh, S. A. Leibenzon, V. D. Maksimenko, A. F. Tregubenko, B. S. Speranskii, V. P. Frantsov, and V. F. Smolyakov (*Stal'*, 1961, (4), 322–326) An examination of the defects found in electro-slag ingots and their causes is reported. Stable electrical conditions are most important to avoid both surface and internal slag inclusions. Macro-defects are practically eliminated by the conditions specified.

PRODUCTION OF FERRO-ALLOYS

Ferroalloys, steelmaking and the future F. E. Van Voris *J. Met.*, 1960, **12**, Dec., 940, 944) Recent developments in improved ferroalloys and their use in the production of various types of steel are summarized (11 refs).

Raw materials handling for ferroalloy plants R. A. Davidson (*AIMME, Proc. Elec. Furn. Conf.*, 1959, **17**, 175–182) Raw materials handling at the Vanadium Corp. of America's ferroalloy plant is by means of a storage and batching. The author gives details of the equipment and its operation.—G.F.

Reducing agents for submerged-arc manufacture of ferroalloys A. D. Gate and H. D. Wedge (*AIMME, Proc. Elec. Furn. Conf.*, 1959, **17**, 184–189) The authors compare the use of C, Si, and Al as reducing agents in the electric smelting of ferroalloys, and outline the operation of the submerged-arc furnace. Operating problems in the use of carbonaceous reducing agents are discussed.—G.F.

On the disintegration of low-iron high-carbon ferromanganese I. Tanabe, T. Toyota, and H. Konno (*Nippon Kinzoku*, 1960, **24**, (5), 272–274) [In Japanese] High-C FeMn becomes less stable to water and moisture as the Fe content decreases. With Fe < 5%, it disintegrates in wet air. With Fe < 10%, it is unstable in water. Disintegration is caused by reaction of Mn_3C with water (formulae given).—K.E.J.

FOUNDRY PRACTICE

Men and work in the foundry H. Scholz (*Giesserei*, 1960, **47**, Aug. 25, 451–460) A report of an investigation carried out by the Max-Planck Institute for work physiology on conditions in the foundry and their effects on overstrain, together with a discussion of measures to increase productivity and alleviate working conditions (15 refs).

Report on the Hungarian ferrous and non-ferrous metal foundry industry J. Lacfalvi (*Koh. Lapok-Öntöde*, 1961, **12**, Jan., 18–23) The report is a statistical survey of the production, labour, and equipment of the Hungarian ferrous and non-ferrous metal foundry industry.—P.K.

Present state and future tasks of the Hungarian foundry industry S. Hargitay (*Koh. Lapok-Öntöde*, 1961, **12**, Feb., 39–42) The present state and future tasks of the Hungarian foundry industry in melting, moulding, casting, fettling, and mechanization are discussed.

The problem of evaluating cast iron and the role played by the structure of the matrix A. Collaud (*Giesserei*, 1960, Dec. 15, **48**, 719–732) The conception of 'quality of cast iron' is discussed and qualities obtained under different metallurgical conditions are compared with regard to mechanical properties and structures. New ways of producing high-quality cast irons are indicated (17 refs).—R.P.

Calculation of casting weights M. Callaghan (*Found. Trade J.*, 1960, **109**, Dec. 29, 815–821) The accuracy in weight assessment of a casting is discussed. This may be in connexion with handling transport, ladle, and melting capacity or crane loading capacity. Estimating methods are discussed and illustrated (ratio, displacement, calculated volume; annular castings; irregular shapes; cones; and spheres).—C.V.

Preliminary report on a new running technique K. Pearce (*Found. Trade J.*, 1960, **109**, Dec. 29, 823–826) Normal loose pattern moulding techniques are used and complicated radii have been avoided; the actual dimensions used are not too critical and the yield will be greater than where the more efficient of the well-type sprue bases are employed. The application of this technique to small loose-pattern plated work in non-dressing alloys is considered and it is suggested that it may well be applicable to larger castings. With bends, there may be excessive turbulence and this may preclude its use with dressing-type alloys.—C.V.

Planning a general ironfoundry E. Longden (*Brit. Found.*, 1960, **53**, Dec., 555–564) The early planning of two general foundries producing 250 and 150 t/week of finished castings is discussed with emphasis on mechanical handling systems.—A.D.H.

New trends in the construction of foundries A. Valášek (*Slévárenství*, 1961, **9**, (3), 81–85) [In Czech] Size, location, and specialization of foundries planned for construction in Czechoslovakia up to 1965 are discussed in the light of present planning economics in the USSR.

Vanderbijl Engineering Corporation's Foundries (*Found. Trade J.*, 1961, **110**, March 16, 337–340) This South African Corporation's activities rank among the most important foundries in the Southern hemisphere. The plant is briefly described and various aspects are illustrated.—C.V.

Mechanization of the hand moulding shop H. Bergmann (*Giesserei*, 1961, **48**, April 20, 186–194) The operation capable of mechanization in the hand moulding shop are surveyed, treating the operations of filling moulds with sand (by linked belt conveyors), filling and ramming moulds (by sand slingers) and transporting. Novel features are described.—M.L.

Air flow in cupolas Commonwealth Scientific and Industrial Research Organization (*Found. Trade J.*, 1961, **110**, March 9, 309–311) Fines, present in the coke bed of a foundry cupola detract from operating efficiency by increase of air pressure drop through the bed; this necessitates increased fan hp to maintain airflow. Measurements were made on an experimental scale using a 'voidometer' which is a cylindrical container with tappings at various levels. The effect of 'sandwich' charging is studied and it was shown that with beds of ∼equal proportions of large and small particles, whatever their thickness, there was a lower pressure drop than with an equivalent straight mixture. The work is to be extended to include the present of a metallic charge and in an actual cupola.—C.V.

An installation for heating the cupola blast M. Kaminski (*Prz. Odlew.*, 1961, **11**, (3), 81–85) The cupola gas still containing some CO and H_2 is burnt, its temp. thus rising from 650–1 000°C, and is then passed first through a radiation recuperator and then through a convection recuperator before being exhausted into the stack. The temp. of the air is thus raised to 500°C and such an installation is particularly suitable for cupolas of a capacity of at least 5 t/h.

Metallurgical influences on mechanical properties of induction furnace-melted 13% chromium-steel castings J. Koutsky (*Found. Trade J.*, 1961, **110**, April 6, 430–434) The experimental work (*ibid.*, March 30, 404) is briefly reviewed. Methods of deoxidation with Al, CaSi, ZrSi are discussed and melting and casting temp. are indicated, macrophotographs of fractures of these specimens being shown. It is concluded that the chemical composition of the steel should have a min Cr and C content; Cr and Ni should be ∼equal and the presence of $\not> 20\%$ δ-ferrite is acceptable. Preheated FeCr should be added to the meltdown of the C and steel charge and the melt worked as hot as possible, the temp. of the melt being raised before tapping to obtain the optimum results Final deoxidation is best achieved with CaSi and these steels are insensitive to casting temp. within a 1480–1580° range. Remelting or the use of Cr-steel scrap improves the strength of the castings.—C.V.

Desulphurization of cast iron . . . by electrolyzing slag (*Found. Trade J.*, 1961, **110**, March 23, 363–368) The inherent disadvantage of the cupola in introducing S into the melt is briefly discussed and the work of the NE Institute of Technology's Institute of Foundry Practice Chinese People's Republic is reported. Electrolysis is carried out using dc with the slag as the anode and the molten iron as cathode. It is claimed that up to 97·5% desulphurization can be attained and that the higher the C-content, the greater the desulphurization. The method is discussed in some detail and the theory underlying the reaction is examined.—C.V.

Thoughts on phosphoric cast iron R. V. Riley (*Brit. Foundryman*, 1960, **53**, Dec., 549–555) The influence of P on the mechanical properties of cast iron is reviewed and the improvements obtained by spheroidization of the phosphide eutectic are described.—A.D.H.

Practical observations on mould stability as a factor in controlling the soundness of grey iron castings A. D. Morgan and J. M. Greenhill (*Brit. Found.*, 1961, **54**, Feb., 45–53) Unsoundness in brake drum, large roll, valve body, and crankshaft castings were investigated by weighing and measuring. Mould rigidity was of fundamental importance in controlling the incidence of porosity which was always reduced by increasing mould rigidity.—A.D.H.

Molybdenum-alloyed cast iron used in the construction of engines and motor cars G. E. Ott (*Giesserei*, 1961, **48**, April 20, 223–233) The use of Mo alloyed cast irons in the construction of engine and motor car parts and of car body-drawing tools is surveyed, analysing the importance of the various properties in the different applications (41 refs).—M.L.

Studies on the titanium cast irons K. Kato and S. Kita (*Rep. Himeja Tech. Coll.*, 1960, Feb., 94–104; from *Japan Sci. Rev. Mech. Elect. Engr.*, 1960, **7**, Aug., 275) [No abstract].

The production of nodular cast iron M. Cseh (*Koh. Lapok-Öntöde*, 1961, **12**, Feb., 25–32) Among the various methods considered by the author, treating molten iron with Mg under pressure appears to be the most advantageous for producing nodular cast iron. This method needs the least amount of Mg, and results in the smallest fall in temp. Measures to prevent slagging, and data of the permissible contents

of contaminating elements in the raw materials are also given.—P.K.

The manufacture of cores in waterglass with economy of CO_2 (*J. d'Inf. Tech. Fonderia*, 1961, (122), Jan., 4–5) The results of tests made at the Fonderies Havraises are briefly reported.—S.H.-S.

Shaw process patterns, principles and production I. Lubalin and R. J. Christensen (*Mod. Castings*, 1960, **38**, Oct., 83–94) The history of the process is given, and its value and application are discussed.

Five new tests for controlling shell moulding sand mixtures AFS Shell Mould and Core Committee (*Mod. Castings*, 1960, **38**, Oct., 55–59) The tests described are to determine melting point, hot tensile strength, hot deflection, transverse strength and permeability. These terms are defined, and the test apparatus and procedure are described.

Foundry switches over to zircon sand shell moulds American Steel Foundries (*Steel*, 1960, **147**, Oct. 3, 76) A process permitting accurate duplication and close dimensional control, cutting down subsequent machining, is described, and its operation and advantages briefly discussed.—S.H.-S.

Making large steel castings in zircon sand shell moulds R. H. Herrmann (*Foundry*, 1960, **88**, July, 81–85) Carbon and low alloy steel castings up to 300 lb are produced in resin bonded zircon sand moulds for a foundry with 800t/month current output, 50% low-alloy, 40% carbon, and 10% special alloy, and a high production work capacity of 1 800 t/month. The system automatically processes up to 20 t of coated sand/h, and one man controls sand reclaiming, mixing, and distribution by push-button panels. The operation of the plant from sand preparation to melting is described.

Study on the thermal properties of shell moulds K. Kobayashi (*Imono*, 1960, **32**, March, 159–167) The following properties were studied; (1) The skin formation rate and the time and temperature range of thermal decomposition of phenolic resin; (2) The physical properties of shell moulds; (3) The thermal analysis of shell moulds; (4) The determination of mould constant from the rate of skin formation.

Shell coremaker of unit construction Polygram Casting Co. Ltd (*Metalw. Prod.*, 1960, **104**, Nov. 16, 71) The basic units are core blower, oven feed, oven, knock-out (ejection) table, and corebox return grid. These can be connected together in different arrangements to suit any desired foundry layout. The assembly of these units is illustrated, the whole being at a single working level. The cycle requires that the core blower operator slides the box from the knock-out table to the 1½in dia. blowing orifice. Automatic pneumatic clamping, blowing with a fluidized column of moulding material, and unclamping follow in rapid succession and an interlock prevents blowing prior to the box being clamped. The invested box is then pushed across the pneumatic transfer arm from which it is pushed into the oven and as the box passes over a grid any surplus moulding material drops by gravity leaving a hollow shell core. As the box is passing into the oven, the operative prepares the next core box and thus the investment time, 10–15 s, controls the overall output of the machine. With lower outputs, one operative can both blow cores and strip them as stripping gear can be fitted where necessary. Rotational speed of the oven can be adjusted to give optimum curing time; the oven is thermostatically controlled and can be heated by electricity, town gas, propane, or butane. Surplus moulding material can be returned through a valve without opening the main container; this latter holds 50 lb and can be fitted with automatic topping up. The automatic clamp adjusts itself to all shapes and sizes of corebox up to a max. height of 15in.

Shrinkage of grey cast iron G. Nándori (*Koh. Lapok-Öntöde*, 1960, **11**, Nov., 241–247) The author describes the measurement of linear and volume shrinkage of grey cast iron and discusses the various factors affecting shrinkage, such as graphite content, chemical composition, etc.—P.K.

Examining the causes of shrinkage defects in grey iron castings A. G. Fuller and K. E. L. Nicholas (*BCIRA J.*, 1961, **9**, March, 173–184) The four factors giving rise to shrinkage defects are examined: (a) casting expansion in soft moulds; (b) unsuitable chemical composition; (c) incorrect pouring temp.; and (d) the degree of eutectic nucleation of the iron. These factors may operate singly or in combination. practical examples are given and remedial suggestions are offered. Appropriate tests are given and all testing procedures are kept simple.—C.V.

Casting defects caused by the expansion of green foundry sands W. Patterson and D. Boenisch (*Giesserei*, 1961, **48**, Feb. 23, 81–87) The causes and mechanism of formation of several types of defect caused by sand expansion are enumerated and discussed, and means for their elimination described.

Study of hot tearing in steel castings K. Beckius, M. C. Flemings, and H. F. Taylor (*Inst. Hierro Acero*, 1961, **14**, Jan., 10–26; Special Number) [In Spanish] The development of a hot-tearing test to measure the susceptibility of cast steel to hot cracking is described in detail. The variables to be studied were mould resistance, steel composition, and casting temp., and no special instruments were used. The test finally evolved is suitable for investigation and control purposes in foundries. The results help to explain the relationship between casting design and feeding and external hot-cracking and the formation of hot-tears. External tears begin to form when solidification commences but they may be eliminated if sufficient metal remains liquid. Open tears and internal cracks can be avoided by designing so as to provide adequate feeding.

Practical notes on ram-off defects A. A. Timmins and A. D. Morgan (*BCIRA J.*, 1961, **9**, March, 237–243) Castings, which at first sight appear to be cross-jointed, may actually be suffering from 'ram-off' defect. The cure of this is discussed and the pattern, moulding machine, moulding boxes, and quality of the sand are examined separately. An example is given but it is stressed that each case has to be separately assessed.—C.V.

Blow-holes and inclusions in a grey iron casting (*Foseco Foundry Practice*, 1961, (145), Feb., 1–3) A valve component is examined and analysed as to causes of blow-holes and possible causes discussed and remedies suggested.

Porosity in unalloyed cast steel O. Heide (*Giesserei Techn.-Wiss. Beih.*, 1960, (30), Oct., 1655–1668) [In German]; also (*Inst. Hierro Acero*, 1961, **14**, Jan., 27–45, Special Number) [In Spanish] Factors influencing the occurrence of porosity in steel castings are discussed; the behaviour of unalloyed carbon steels in bentonite sands and shell moulds was examined, using a special pattern and a specially developed sampling method (30 refs).

Improving the quality of castings by new testing and control procedures H. E. Henderson (*Iron Worker*, 1960–61, **25**, Winter, 26–31) The testing methods and programme in the works cited are described in detail. Carbon and sulphur contents, microstructure, tensile strength, yield strength, elongation, resin melt and hot shell tensile results, creep deformation, green core impact, and permeability are determined.

The improvement in the quality of foundry works indices H. Geissler (*Giessereitech.*, 1961, **7**, March, 71–76) The indices of moulding, sand preparation, and melting operations were studied having in view an improvement in their quality. These three operations were chosen only for their strong interdependence in modern mechanized foundries. The factors influencing the individual indices are examined and their effects are evaluated. The results are discussed and must be developed further in order to achieve a solution of the problems encountered in foundry work.—M.L.

New concept reduces casting cleaning costs E. Kreger (*Mod. Castings*, 1961, **39**, March, 51–53) The increased metal yield, better casting quality and thus low cleaning cost, where innerbore risers have been used, is discussed. Experience in the use of this new method is summarized.

Blast unit cuts cost in deburring castings Clinton Engines Corp. (*Foundry*, 1960, **88**, Nov., 196) Economics resulting from the replacement of a hand operation for deburring die castings by blast deburring in large batches, with details of equipment, are described.

VACUUM METALLURGY

Vacuum melted materials H. C. Child (*Proc. Eng. Materials and Design Conference, Feb.* 1960, *London*, 1960, F, pp.22) The various types of material being vacuum melted are summarized: (1) Ti (a) creep-resistant alloys for gas turbine compressor discs and blades, (b) high-strength alloys for structural parts, (c) sheet alloys; (2) martensitic Cr steels; (3) austenitic steels and Ni base alloys; (4) Ni base alloys; (5) ball-bearing materials; and (6) ultra-high-tensile steels. These different groups are discussed (27 refs).—C.V.

Vacuum degassing of steel D. E. Parsons and W. A. Morgan (*Can. Min. Met. Bull.*, 1961, **54**, Feb., 162–169) A brief review of current literature pertaining to vacuum degassing or vacuum casting of steel as practised in the USA, Germany, and the USSR. Operating pressures, reduction in gas contents, and improvements in hydrogen segregation, steel cleanliness, and mechanical properties, obtained with various techniques are described, and results are summarized.—S.H.-S.

Vacuum degassing and vacuum casting of steels (*Can. Mines, Research and Special Projects Report for* **1960**, 1961, 11–12) The effect of vacuum-spray-casting and vacuum-ladle-degassing of 500-lb melts of 0·30%C steel was studied and compared with 12in × 12in × 4in slab castings made from degassed and non-degassed metal, after sectioning and heat-treatment of 6in × 6in × 4in samples. Vacuum-cast slabs showed a fine equiaxed macrostructure with characteristic solidification pattern in which the zone of porous metal last frozen is displaced from the centre to a sub-surface in the casting. Non-degassed castings contained central porosity with metal tapped $>1600°$ and tensile bars from the centre of these gave reduced ductility and contained 'fisheyes' on their fracture surface. Baking at 250° for 70 h partially restored ductility being fully restored by normalizing and tempering of 0·505in bars. With ladle-degassed melting, improved tensile ductility was obtained without improvement of impact or notched-bar fatigue properties; pouring was into dry sand moulds. A correlation was observed between tapping temp., gas porosity, and mode of solidification, the loss in tensile ductility being greatest in the metal last frozen of melts tapped at the highest temp. Loss of ductility and incidence of fisheye fractures increased with riser H_2 content, being more persistent in non-degassed than in degassed castings.—C.V.

Vacuum alloys: the superheating of solids D. S. Kamenetskaya and I. B. Piletskaya ('*Problems of Metallography and the Physics of Metals*', 1959, 39–41; translated from Russian) The ability to melt *in vacuo* is discussed and the examples of Mg and Zn are given, it being stated that sublimation occurs, not boiling. A pressure-temp. coordinate diagram is examined and a further number of substances are studied, Mg, Zn, Cd, Mn, Al, Al_2O_3, SiO_2, NaCl, camphor, benzoic acid, and naphthalene, it being shown that these cannot be melted *in vacuo* at a pressure of, or lower than 10^{-2} mm Al can be melted *in vacuo* but can be heated in a liquid state up to $\sim 1000°$ while the remaining substances evaporate long before the melting temp. is reached. In the experimental work it was shown that Mg could be superheated at a temp. > the sublimation temp. and it is considered that this can be explained by the nature of the interatomic bond; in sublimation there is a marked difference, but in melting it is considesably less.—C.V.

On the preparation of Fe–Ni base high permeability magnetic alloys for vacuum casting and sintering G. Brossa, A. Ferro, and G. Venturello (*Met. Ital.*, 1961, **53**, Jan., 17–23) [In Italian] The relative advantages of the production of high permeability Fe–Ni alloys by vacuum melting or by sintering are compared.

REHEATING FURNACES AND SOAKING PITS

Reconstruction of pit furnaces in a Hungarian blooming mill A. Biro (*Koh. Lapok*,

1960, **93**, Nov., 518–521) In the blooming mill of the 'Iron and Steel Works Lenin' in Diósgyör, Hungary, the old regenerative pit furnaces will be replaced by recuperative live pits fired at their upper part in one direction, generally with top gas, or occasionally with producer gas. The heating capacity of the pit furnaces will then increase by about 30%.

The supply of hot ingots to soaking pits V. M. Sobolev (*Stal'*, 1961, (3), 280–285) Advantages of transferring ingots to the pits as hot as possible and the organization required for speeding up the transfer are discussed.

Automatic and rotating plate machines for various induction heating processes (*Usine Nouv.*, 1961, **17**, March, 23, 32–33) [In French] This article describes the use of automatic and rotating plate machines for welding and brazing, hardening and annealing, and heating before forging.

Experiences with the operation and design of heating furnaces of rolling mills in the Peoples' Democracies B. Kaspřik (*Hutn. Listy*, 1961, **16**, Feb., 108–113) [In Czech] Modernization of rolling mills, to increase output, improve quality, and achieve economy of production is described. The author tells of improved design, maintenance, and operation of heating furnaces, and rolling mills in USSR and the 'Peoples' Democracies'. Repairs and efficiency of furnaces can be improved with a more mechanized system of repair and attendance.

HEAT-TREATMENT AND HEAT-TREATMENT FURNACES

Two heat-treating furnaces do the work of 3 F. Fensel (*Foundry*, 1960, **88**, Nov., 208, 210) Increased production results arising from simplified handling, with details of the new equipment are described.—S.H.-S.

Linked line methods move into heat treatment K. W. Hards (*Metalw. Prod.*, 1961, **105**, March 29, 49–53) The technique of linking standard machine tools to an automatic production line is now introduced to the heat-treatment shop. The furnace line at the Daventry East works of British Timken is described where complete mechanical handling of tapered roll-bearing cups and cones is installed together with automatic storage facilities.—C.V.

The thermal characteristics of industrial furnaces H. Southern (*Glass Techn.*, 1960, **1**, Dec., 237–242) These are mathematically discussed; the factors determining a successful furnace are stressed and the assessment of test data and the application of the fundamental equations relating to the distribution of heat within the furnace chamber are discussed in considerable detail.—C.V.

The aerodynamics of gases in continuous furnaces M. M. Korotaev (*JISI*, 1961, **199**, Sept., 15–18) [This issue].

Induction heating in the metal industries. I. Heating and melting A. H. Hunt (Capacitors) Ltd (*Edgar Allen News*, 1961, **40**, March, 53–54) The principles are briefly reviewed with a discussion of power factor. The article is the first of a series.—C.V.

An interesting induction heating installation (*Wild-Barfield J.*, 1961, **8**, Mrach, 8–10) Some brief details are given of the equipment used for hardening, tempering, and shrinking ring gear components in an Australian motor car factory. The units are clearly illustrated and it is stressed that once the initial heating and setting up have been carried out, the work is repetitive and independent of the skill of the operating personnel.—C.V.

Practical aspects of induction applied to equipment for heat-treatment and melting J. C. Howard (*Inst. Hierro Acero*, 1961, **14**, Jan., 73–87, Special Number) [In Spanish] An illustrated review of the various types of induction furnaces is given together with a discussion of their advantages, disadvantages, and applications.—P.S.

Coreless low-frequency furnaces B. Hands (*Ing. e Ind.*, 1960, **27**, Nov., 139–160) The design and working characteristics of these furnaces are described. Details of the electrical and control equipment are given.—P.S.

The heat treatment of steel E. Gregory and E. N. Simons (*Edgar Allen News*, 1961, **40**, Feb., 33–34) A comparison is made between salt and lead baths, and between salt baths and air or controlled atmosphere furnaces. Temp. measurement is also discussed.

Turbulent combustion of gaseous fuels in industrial furnaces T. Senkara (*Hutnik*, 1961, **28**, (1), 6–13) The rate of heat evolution depends on the excess of air and the amount of oxygen. Also the amount of gas and air and the rates and direction of flow as well as the position of the burner have some influence. Lastly the mixing of primary and secondary air, in particular the manner of mixing, must be taken in account when calculating the distribution of temp. and their changes.

Protective and reactive gases in the heat treatment of metals W. W. Minkler (*Blech.*, 1961, **8**, Jan., 27–29) In the contemporary state of heat-treatment of metals in controlled atmosphere furnaces the gases are used for reduction of metal oxides as well as for gas-alloying carburizing and decarburizing, nitriding, and denitriding—and the term 'protective gas' is therefore erroneous. A new comprehensive term is suggested: 'Protective and reactive gases' for the gases and 'controlled furnace atmosphere' when such gases are used or formed by the heated metal itself.—M.L.

Low-cost furnace atmospheres from blast-furnace gas Incandescent Co. (*Iron Coal Trades Rev.*, 1961, **182**, Feb. 17, 353) The use of N_2/H_2 mixtures (Hy-nitrogen or HNX) is discussed. This gas provides a completely inert atm. for bright annealing and does not form soot during cooling since it contains no CO, and H_2 is present in sufficient concentration to combine with any O_2 that may leak into the furnace and also to prevent water vapour from forming blueing. Blast-furnace gas (30%CO + traces H_2, $N_2 + CO_2$) is first partially burned and the gases pass to a heat exchanger and cooler to reduce the temp., CO_2 being removed by monoethanolamine. The composition of the gas is N_2 93–99% and CO 1–7%. Steam is then introduced and the gases are preheated prior to entering the shift reactor where CO is converted to CO_2 and an equivalent volume of H_2 is produced; the CO_2 is again removed. The wet H_2/N_2 gases are then dried. Thus blast-furnace gas may be used for all atmospheres thereby reducing the consumption of coke-oven gas which is normally used for this purpose.

Prevention of explosions in furnaces and stoves (*Fonderie*, 1961, Jan., 26–30) The mechanism of formation of explosive mixtures in furnaces and ovens is discussed. Detailed recommendations are made for presenting explosions when using solid liquid or gaseous fuels. Means of limiting the effects of explosions are referred to briefly.—R.P.

Sub-zero heat treatment tests G. Timo (*Met. Ital.*, 1960, **52**, Dec., 849–854) [In Italian] This article describes the heat-treatment cycles examined which enable the effect of under-cooling temp., time, and the number of under-cooling cycles to be controlled. The results are given in detail.

Economical uses of alloys in steel production W. Küntscher (*Neue Hütte*, 1961, **6**, Feb., 72–77, 79) [In German] Organizational and metallurgical measures are presented for the saving of alloys by heat-treatment.—R.S.F.C.

Furnace control adds precision to job-shop gear production Brad-Foote Gear Works (*Iron Age*, 1960, **186**, Nov. 17, 154–155) The need for careful planning and close control in the handling of job lots of precision gears is briefly discussed.—S.H.-S.

Effect of carbide stringers on the distortion of die steels during heat treatment K. Sachs (*Met. Treatment*, 1960, **27**, Nov., 455–460) The author points out that alloying additions can influence the dimensional stability of steel during heat-treatment. This is illustrated by data obtained from the behaviour of non-distorting die steels which contain Si and Mo. The paper is concluded by a study of the relative importance of thermal stresses and transformation stresses on distortion.—A.H.M.

Effects of carbide stringers on the distortion of the steels during heat treatment K. Sachs (*Met. Treatment*, 1960, **27**, Dec., 487–492) An analysis is given of the combined effects of dimensional changes caused by thermal stresses and by the volume changes associated with martensite formation. The analysis is applied to a number of shapes and a comprehensive table given of the expected dimensional changes. The article is concluded by a consideration of the distortion due to differences in expansion characteristics.—A.H.M.

Oxidation and decarburization of steel in furnaces fired with natural gas K. M. Pakhaluev, I. V. Medvedeva, V. V. Andreeva, and M. N. Kul'kova (*Stal'*, 1961, (2), 160–163) Non-oxidizing conditions by the use of incompletely burnt natural gas are successful if the air is sufficiently preheated in conventional air heaters. Other methods of protection are also being examined.

The heat treatment of dies. III M. Tossi (*Tratt. Term. Met.*, **3**, Sept.–Oct., 15–16, 18–24) [In Italian] This part deals with matrices and blanking dies and works practice, particularly annealing. Micrographs illustrate the results of heat treatment of test pieces.

Bright annealing stainless tubing in twin muffle furnace Trent Tube Co. (*Indust. Heat.*, 1961, **28**, Jan., 64–67) This gas-fired atm.-controlled furnace has two Inconel muffles for heating, a water-jacketed cooling section, and Cr–Ni conveyor belts. Depending on shape and composition, if processes 400–700 lb of pipe or tubing per h.—K.E.J.

Heat processing of silicon iron alloys or electrical steels. I. A discussion of process and equipment B. A. Ruediger (*Indust. Heat.*, 1961, **28**, Jan., 26–35) Details are given of the composition, properties, commercial classification, and selection of Si–Fe alloys. Full data are given for melting, pouring, reduction, and heat-treatment. Equipment is described for normalizing, annealing, and thermal flattening treatments. (Feb., 262–266) Details are given of various treatments which may be adopted by steel users, e.g. stress-relief annealing after cutting operations, coating (which governs the annealing atm.), and oxidation and blueing.

The heat treatment of cast iron with lamellar and spheroidal graphite structures H. Borchers and G. Haberl (*Giesserei Techn.-Wiss. Beih.*, 1960, (3), Oct., 1679–1693) The literature on the heat-treatment of cast iron with lamellar or nodular graphite is classified and reviewed (123 refs).

Isothermal heat treatment R. C. Stockton (*Efco J.*, 1960, **1**, Nov., 2–10) This treatment, as applied to steel, means the transformation of austenite to the required physical state at a pre-selected temp.; remarkable consistency of physical properties results. Where cyclic annealing is practised, it is often found that considerable time is saved and more uniform softness results. With hard martempering, this involves quenching to a temp. a few degrees above that at which martensite forms and holding within the time limit available until uniformity is attained; this is followed by air cooling with the transition occurring on a very slight temp. gradient from outside to centre. The TTT curves are discussed and examples are given to show the comparable physical characteristics of SAE 1085 steel isothermally treated and conventionally oil hardened. The shaker hearth furnacd with salt bath quench is illustrated and described.—C.V.

Automatic control of the CO/CO_2 ratio in gas-malleablizing R. Deinhard (*Giesserei*, 1960, **47**, Sept. 8, 492–497) Control equipment for the annealing atmosphere in a malleablizing furnace for white iron is described. Two continuous infra-red gas analysers are used for determining the CO and CO_2 content, and a photo-electric control adjusts the air control valve (10 refs).

Inspection of the malleablizing tunnel furnace in the 'Iron and Steel Works Csepel' in Hungary J. Gerencsér (*Koh. Lapok-Öntöde*, 1960, **11**, Dec., 277–283) The paper contains the results of an inspection and, based on this, a proposition for reconstruction of the malleablizing tunnel-furnace in this works.—P.K.

Industrial research an the heat treatment of the MT permanent magnet S. Miyata and N. Makino (*Nippon Kinzoku*, 1960, **24**, (3), 135–138) [In Japanese] The optimum temp. for quenching of the alloy (2%C, 8·15%Al, Fe bal.) is 1210–1250°C. With interrupted quenching, hardening cracks are smaller than

with normal quenching, but magnetic properties are impaired. Annealing at 800°C makes the alloy machinable.—K.E.J.

The tempering of quenched high speed steels J. Papier, G. Pompey, and A. H. Michel (*Rev. Mét. Mém. Sci.*, 1960, **57**, Nov., 829–844) A discussion of the results of tempering quenched high-speed steels continuously in the differential dilatometer or the thermomagnetometer. Above 500°C there are four stages, the 1st and 3rd corresponding to an expansion and increase in magnetism, and the 2nd and 4th to a contraction. The mechanism of these effects is discussed. (**Conclusion**) (Dec., 949–971) After austenitizing at 1280°C, duplicate samples of several grades of high-speed steel were quenched, one in oil at room temp., the other in liquid air, the samples were then tempered at various temp. by continuous heating in the dilatometer or the thermomagnetometer. These results are discussed in terms of the structures obtained (31 refs).

Studies on tempering gamma type heat resisting alloys. I. Change in physical properties during the tempering of gamma-type Fe–Co–Cr–Ni base heat resisting alloy, LCN–155 Y. Imai and T. Masumoto (*Tetsu-to-Hagane*, 1961, **47**, Feb., 139–145) The tempering process of the solution-treated γ-type heat-resisting alloy (Fe–Co–Cr–Ni) and the effects of solution temp. together with the influence of C, N, Mo, W, and Nb additives was studied by measurement of dilation, specific heat, electrical resistance, and hardness. Tempering by water quenching was divided into two distinct stages, at 500° and 750°. In the first, increase in electrical resistance, evolution of heat, and length contraction, but no change in hardness were noted: it was considered that these changes were not due to pptn. of carbide or nitride but to unknown changes in the quaternary alloy. In the second stage there was a decrease in electrical resistance, evolution of heat, contraction in length, and a remarkable change in hardness; these changes are caused by the precipitation of carbide, nitride and intermetallic compounds. The extent and rate of pptn. is greatly influenced by additives and solution-treating temp. (22 refs).—C.V.

FORGING, STAMPING, DRAWING, AND PRESSING

Modern trends in the manipulation of metals D. F. Galloway (*Prod. Eng.*, 1961, **40**, Feb., 83–98) A review of metal forming as opposed to metal cutting processes is presented, and developments in extrusion techniques and precision forging are described, with new techniques in precision rolling, sheet forming, and deep-drawing, concluding with a plea for more standardization of press and press tool dimensions.—S.H.-S.

International conference of forge masters between the 20th and 29th of April, 1960 in Budapest (*Koh. Lapok*, 1960, **93**, August, 378–381) This article is a report on the proceedings of the International Conference of Forge Masters between 20 and 29 April 1960, in Budapest. In one of the treatises, academician Geleji deals with the flow of metal and determination of power consumption in forging processes.—P.K.

Hammers for open forging and die forging made in Poland K. Bosiacki (*Hutnik*, 1960, **27**, (11), 418–424) The author tabulates the types of hammers working at the present time as well as those to be in operation by 1965. The technical characteristics, possible line of future development, the main physical features as well as uses of the various hammers are discussed.

Drop forging of undercut work-pieces T. Toth (*Koh. Lapok*, 1960, **93**, Oct., 452–455; Nov., 494–497) The author describes the drop forging of undercut workpieces, particularly of fire-hose clamp joints, in Hungary.—P.K.

Robot handles forging job (*Iron Age*, 1961, **187**, March 2, 96–97) A robot machine, designed by Consolidated Controls Corp. of Bethal, Conn., called the Unimate, to take over repetitive routine jobs, has a mechanical brain that remembers 200 sequential commands, and an arm duplicating the functions of the human arm, which will act in accordance with the brain's commands.—S.H.-S.

Preparation of metal for cold upsetting V. F. Belik (*Stal'*, 1961, (2), 183–184) Supplementing a previous article by Smol'yanov and Shushakov (*ibid.*, 1959, (12), 1136–1140), the use of material of greater thickness than the 6 mm there described, a rimming Si-free steel is preferred.

Gears forged by German process (*Steel*, 1961, **148**, March 20, 100–101) A forging system which applies hot pressing in place of machining, developed by Bayerisches Leichtmetallwerk of Munich, for gear production, is briefly described.—S.H.-S.

Expert cites forging research needs H. B. Goodwin (*Steel*, 1960, **147**, Nov. 21, 102–103) With the object of increasing production, research into the fundamentals of metal flow, the distribution of forging energy, methods of operation, protective coatings, and inert atmospheres, with improved heating and higher forging temperatures, are suggested fundamental to more formalized programmes.

Transfer-broached crankshafts K. W. Hards (*Metalw. Prod.*, 1960, **104**, Nov. 9, 75–77) A transfer broaching unit for machining crankshaft webs prior to pin turning has replaced a battery of six milling machines at the Austin Motor Co. Ltd. Labour requirements have been reduced from three operatives to one and capacity has been increased by 20%. General details are provided of the loading, processing, and of the turnover device where the crankshafts are turned through 90° for transfer to the second broach where webs on the other side are machined.—C.V.

The problem of the quality of large steel forgings P. Bastien (*Rev. Mét.*, 1960, **57**, Sept., 815–826) An account of the study of heterogeneities and discontinuities in large steel ingots, and the techniques of the ultrasonic inspection of large steel parts (21 refs).

Plastic working F. W. Boulger (*Mech. Eng.*, 1960, **82**, Sept., 70–72) A review with 35 refs.

Questions concerning the development of testing techniques for determining the formability of sheet G. de Witte (*Rev. Mét.*, 1960, **57**, Sept., 835–841) Terminology, and factors governing choice and scope of test methods are considered.

Fabrication methods evaluation J. G. Frantzreb (*Mod. Castings*, 1960, **38**, Dec., 97–106) Casting, forging, shaping, and joining are discussed, and the way in which—combined with choice of material—the job in hand affects the process used is indicated.

The producers' interest in steel consumers' quality problems H. C. Swett (*Reg. Tech. Meet. AISI*, 1958, 307–354) Problems related to quality, defects and their causes, the types of tests used, etc., are briefly summarized and a series of selected samples is presented. This covers ineffective and delayed tempering, excessive hardness, inadequate quenching, forging too cold, failure by deep stamping and fatigue, and faulty design and treatment. Illustrations and photomicrographs are included.—C.V.

How to pick the right forming lubricant F. M. Arnold (*Steel*, 1960, **147**, Nov. 21, 98–100) Lubricants and lubricating agents from oils to duplex coatings are discussed, and a check list with operations arranged in increasing order of cold work, pressures encountered, and strength of film required, with lubricants in order of increasing effectiveness and probable cost, is presented.—S.H.-S.

Colforg cold forming machines and equipment (*Machinery*, 1961, **98**, Feb. 8, 308–312) Units of the cold forging installation (shown at the Machine Tool Exhibition, Hanover, 1960) are shortly to be brought into operation in this country at the works of Cold Forging Ltd. They are illustrated and their working is discussed.—C.V.

Magnetic forming for swaging tubes US Naval Research Laboratory (*Metalw. Prod.*, 1960, **104**, Dec. 21, 71) A new method of compressing metal to shape by using magnetic forming is described, and the possibilities when the process has been further developed, if magnetic force were to be coupled with dies, are suggested as 'almost limitless'. The working of the magnetic swager is briefly described and several possible commercial adaptations are suggested.—S.H.-S.

On the determination of stresses during the working of metals by pressure I. Ya. Tarnovskii, A. A. Pozdeev, and N. N. Krasovskii (**Obrabodka metallov davleniem, Vypusk tretti, Metallurgizdat*, 1954, 5–22) Models for rolling and upsetting on various simplifying assumptions are set up and calculations formulated. The results are in reasonable agreement with measured values.

Trimming 08kp steel sheet (GOST 914–56) for very deep drawing F. D. Ivanov (*Stal'*, 1961, (1), 57) A note from Novosibirsk. Allowance of 1·5–2·5% for trimming for sheets of all qualities and thicknesses is recommended.

Drawing conditions for rolled Bessemer steel rod A. M. Bichuch (*Stal'*, 1961, (1), 84–86) The low ductility and content of inclusions lead to many breakages. Drawing down to 4 mm dia. can be carried out by methods given with somewhat reduced output compared with OH steel. Drawing below 4 mm is not recommended.

Adapter turns presses into stretch formers Cyril Bath Co. (*Steel*, 1960, **147**, Nov. 7, 116) A stretch-forming attachment with jaws gripping blanks on two sides and stretching them before male and female dies mate to form the metal are presented, with data on operations and examples, and this is suggested for regular production work.—S.H.-S.

Working stresses set up in drawn material, when leaving the die A. Peiter (*Draht*, 1960, **11**, Nov., 695–702) A mathematical treatise on the total stresses set up in drawn rods of steel at the moment of leaving the die. These working stresses are made up of a residual stress and the spring-back stress. Results of experiments with various die shapes are reported (24 refs).

A new method of hot deep drawing of sheet metals M. Miyagawa (*Mem. Fac. Techn. Tok. Univ.*, 1960, (10), 709–718) A new hot deep-drawing process proposed by the author represents a great improvement in single-stage operation. It seems that the high drawing rate in this process is obtained by the favourable relation between a lowered resistance to radial draw deformation of the heated blank flange and the high strength of the cooled wall after drawing, and in addition by the radial-draw deformation due to the transient thermal stresses caused by rapid cooling. In this paper, the outline of several preliminary tests is given and the results of drawing by one of the equipments used in preliminary tests are described (11 refs).—C.F.C.

Forms, shapes and composites (*Mat. Design Eng., Materials Selector Issue*, 1960, **52**, mid-Nov., 365–407) Design features, castings, extrusions, sheet metal fabrications, patterned sheet, forgings, metal powder parts, screws, tubes, and wire and clad metals are listed with tables of tolerances. Plastics and rubber are included with ferrous and non-ferrous metals.

'Fluid-form' process H. Möller (*Engineer*, 1960, **210**, Dec. 9, 968–970) This is carried out by means of an attachment by which a blank can be given an irregular shape through plastic forming in a simple tool with a cavity corresponding to the shape of the finished part, using a flexible punch which also works as a blankholder. This is described and drawings of the press cycle are given; the punch consists of a cylinder with a telescoping piston, the lower end of the cylinder being closed by a rubber diaphragm and the intervening space being filled with oil.—C.V.

Can explosive forming solve your design problems? E. L. Armstrong (*Iron Age*, 1960, **186**, Nov. 24, 85–87) A method whereby explosives, suitably controlled, can perform a wide variety of foundry tasks, particularly in light metals and plastics, is described. Each charge serves a dual role, replacing the forging press and male die, speeds prototype and final-run fabrication, and reduces need for annealing operations. Similar and dissimilar materials, e.g. copper, stainless steel, and Al, can be bonded together or to each other, spinning can be eliminated, tolerances reduced, and unsymmetrical parts formed rapidly and easily.

British developments in explosive forming W. S. Hollis (*Metalw. Prod.*, 1960, **104**, Nov. 9, 78–81) Extensive use is made of single-piece dies; for small lots these are simple and backed with a heavy mass of shock sustaining material

such as Kirksite or Kayem alloy and epoxy resins have also been used. Large cylindrical and conical components are usually formed to cast matrix of these materials and supported in a peripheral nodular cast iron ring ~8in thick to maintain the radial compressive and peripheral tensile stresses within the elastic range. The various explosives and actuators are indicated and briefly discussed together with the arrangement of the dies and charge. If vacuum equipment is used, this is operated at about 3 mm Hg which is sufficient to remove entrapped air. Examples of practical applications are given and the costs outlined. An average component will involve material costs of 1*s.* 6*d.* to 3*s.* to form and production rate would be 2–4 per h.—C.V.

Investigations concerning the establishment of the manufacturing technology of high quality wires for prestressed concrete G. Sirbu (*Met. Constr. Masini*, 1960, **12**, (12), 1053–1058) The metallurgical and mechanical properties of steel wires and their mutual relationships in different hot and cold treatment processes were studied. The main factors influencing the mechanical characteristics of wires for prestressed concrete were determined, and an optimal technology, as well as technological flow and the necessary installations, were developed for wires of 5 mm dia., on the pilot plant scale.—M.L.

Tooling for cold extrusion R. A. P. Morgan (*Sheet Metal Ind.*, 1961, **38**, Feb., 99–122) A comprehensive, informative, and well-illustrated paper dealing with extrusion-die design, steel inserts, tungsten carbide dies, lubrication of tools, punch design, tool steels, and heat-treatments, deviations of components from tool dimensions, tool costs, and their expected life.—A.H.M.

Cold extrusion of ferrous and non-ferrous materials R. Tilsley and F. Howard (*Product Eng.*, 1961, **40**, March, 176–196) A general, but somewhat detailed review of current practice with illustrations and tables (13 refs).—C.V.

Experiences in the industrial production and use of cold-extruded steel components R. E. Okell (*Sheet Metal Ind.*, 1961, **38**, Jan., 14–20) The article is an account of the factors governing the participation of cold extrusion in industrial production. The factors discussed by the author include the components choice and design, design of pressing stages and tooling choice of steel for cold extrusion, preparatory treatments, and the use of cold-extruded parts.

ROLLING MILL PRACTICE

The thermal expansion of chilled cast-iron and its effects on the internal stresses in rolls R. Kamenský and L. Hyspecká (*Hutn. Listy*, 1961, **16**, (1), 38–41) [In Czech] A study was made of the effect of chilling on the thermal expansion coefficients of the resulting cast-irons of varying grey cast-iron contents. These effects must be considered in the heat-treatment of surface hardened rolls if the formation of tears or fractures is to be avoided.—P.F.

Cast rolls for steel mills J. Bell (*Acorn*, 1960, **4**, (2), 9–11) Five types of roll are summarized. Comment is made of the lack of standardization, it being rare for two mills to employ the same pass design for any given section. A section drawing is given showing the pass design of a pair of rolls illustrating how a reheated bloom is passed back and forth between the rolls to form the shape and size required (6in × 3½in angles). In this diagram the roughing passes (1–3) and finishing passes (4–8) are clearly shown, with the changing contours after each step.—C.V.

Durability and wear of rolling mill rolls W. Gernhard (*Blech*, 1961, **8**, Feb., 131–134) The driving conditions in the rolling mill frame are an important factor in the evaluation of durability and wear of the rolls. Precautionary measures are suggested for reducing wear of rolls and increasing durability.—M.L.

Roller bearings in modern rolling mills Strafe (*Rev. Techn. Luxembourg*, 1960, **52**, Oct.–Dec., 219–226) [In German] Examples of the use of roller bearings in various types of housing, including straightening machines are given, with diagrams and comments.

The cogging mill G. Elwell (*Acorn*, 1960, **4**, (2), 4–8) A brief illustrated description of the installation.—C.V.

New large slabbing mill starts operation: Annual capacity 2,400,000 MT (*Far East Iron Steel Rep.*, 1960, **56**, Aug., 11) [In English] Data are given for the new automatically controlled mill at Fuji Iron and Steel Co.'s works at Hirohata; it is a two-high reversible mill of roll length 2·286 m.—K.E.J.

TV measures beams in hot mill Bethlehem Steel Co. (*Iron Age*, 1960, **186**, Nov. 3, 81) A wide-screen TV measures shear lengths of I-beam and wide-flange blanks as they emerge from blooming mill stands. The system ensures greater accuracy, less physical effort, and better product control.—S.H.-S.

Up-to-date small-section trains A. Komlósy (*Koh. Lapok*, 1960, **93**, Aug., 363–365; Sept., 390–394) The author discusses the development, present construction, and working of modern small-section trains. In his view, a fully-continuous layout is preferable to other arrangements.—P.K.

The new rod, profile and wire rolling mill of Böhler & Co. in Kapfenberg (*Machinenwelt Elekt.*, 1961, **16**, (3), 121–122) The new rolling mill for mechanical and automatic production of rods, profiles, and wires, from Fe and quality steels is described, its main features being long continuously rolled shakes of up to 400 m, giving low waste, of much importance in quality steels, high rolling speeds of 24 m/s, the monthly capacity being 4000 t.—M.L.

A new method of rolling T-sections J. Vojkovský and M. Redr (*Hutník*, 1961, **11**, (1), 16–18) [In Czech] A new method recently developed at the Klement Gottwald Steelworks in Ostrava is described. Instead of rolling single T sections, double T-sections are rolled and separated in the course of consecutive passes by shearing through the centre, two T-sections resulting in the process.—P.F.

Mechanization and production accountancy in the hot rolling shops of the Klement Gottwald Steelworks in Ostrava J. Nečas (*Hutn. Listy*, 1961, **16**, (1), 31–38) [In Czech] A detailed account is given of the administrative aspects of planned production.—P.F.

Starting up the process of rolling lightened sections from low-alloy steels C. V. Makaev, N. P. Skryavin, M. Rabinovich, V. A. Shadrin, and V. D. Korschhikov (*Stal'*, 1961, (3), 240–245) The economics of the thinner girders and channel sections are discussed and it is shown that these can be rolled with the same roll passes as for carbon steels, though costs are higher and output lower. Heat-treatment of the rolled sections by quenching and tempering should be tried.

Forming bumpers by rolling (*Mach. Shop Mag.*, 1961, **22**, March, 135–141) The latest model of the bumper rolling machine evolved by Redman Tools and Products Ltd, producing car bumpers in one piece from flat strip is illustrated and describes, with automatic electrical controls, followed by data on the longitudinal slitting of each formed workpiece to make two finished bumpers.—S.H.-S.

An introduction to the theory and practice of flat rolling C. W. Starling (*Sheet Metal Ind.*, 1960, Nov., 837–846) In this third contribution the author analyses the forces acting on the material being rolled. He also considers the flow of material in the roll gap, speed of bar in the roll gap, the effect of friction, position of the neutral point, rolling load and torque, the plastic curve, and finally the specific roll pressure.—A.H.M.

An introduction to the theory and practice of flat rolling C. W. Starling (*Sheet Metal Ind.* 1960, **37**, Dec., 905–916) The fourth in a series of articles in which the author deals with the following aspects: roll bending, calculation of roll camber, bending of backed-up rolls, lateral bending of work rolls, the four-high driven back-up mill, roll flattening, minimum thickness and elastic curves for rolls.—A.H.M.

An introduction to tne theory and practice of flat rolling C. W. Starling (*Sheet Metal Ind.*, 1961, **38**, Jan., 49–55; Feb., 135–142, 146) This is the fifth article in which the author deals with forces acting on the rolling-mill housing. Various types of housing are considered—conventional, bolted chock, prestressed, and hinge mill housing. The author deals also with the elastic curve of the mill and outlines the methods used for obtaining it. Various aspects of the effect of mill spring on gauge are then discussed. These include modulus of rolls and housing, the elastic-plastic curve, the roll-gap transfer functions, the effect of mill stiffness on automatic gauge control, and taper rolling.

Electronically controlled roll assembly for thick sheet rolling J. Ullmann (*Blech*, 1961, **8**, Jan., 6–8) The application of electronic control to a thick sheet rolling assembly, where the distance between the higher rollers is reduced stepwise, is suggested, thereby increasing the accuracy of the sheet thickness. The principle is based on digital control.—M.L.

Thick sheet rolling mills—their design and construction H. Hover (*Blech*, 1961, **8**, March, 179–183) The design of a rolling mill for thick plates requires preliminary market research, economic calculations, and choice of site. These determine the size of the mill. In some cases a stepwise design is favourable and an example is described. Several problems concerning the machines themselves are dealt with, and their construction is described.

The effect of elastic deformation in the stand on the cold rolling process V. I. Sokolovskii (*Stal'*, 1961, (1), 46–54) A lever device to measure roll deformation was fitted and the deformation zones are evaluated and expressions for the various rolling and groove parameters are formulated, and these are applied to groove design.

Determination of the load of the rolling mill motors in the continuous hot rolling of wide strip with 5 and 6 finishing stands H. Kreulitsch (*Berg-Hütten. Monatsh.*, 1960, **105**, Aug., 192–195) An investigation is described in connexion with the continuous 66in wide strip train of VOEST at Linz, in which two methods of calculation are described; the first method is based on the specific work consumption per ton of rolled stock, and second on a knowledge of the resistance to deformation.

Ohio Steel Foundry Co., maker of rolls, founded in 1907 C. Longenecker (*Blast Furn. Steel Plant*, 1961, **49**, Feb., 148–157) An indication of its history and progress is given and the production facilities in the four main units are outlined.—C.V.

Material and design defects in forged steel rolls A. A. Bradd (*Iron Steel Eng.*, 1961, **38**, Jan., 85–98) Perfect rolling is useless if clean steel is not used and an idealized summary is given of this perfect state. The question of cracked and faulty roll surfaces is examined and the treatment of rolls (forging, annealing, machining, and hardening) and grinding is reviewed.—C.V.

Study of the wear of rolls with particular reference to drag rolling in the finishing pass of hot strip H. Altmeyer, H. Sedlaczek, and F. Fischer (*Stahl Eisen*, 1961, **81**, Feb. 2, 184–194) The study of the wear of the rolls of the finishing pass and of the one before of a hot-strip mill showed that wear follows an exponential function. The constants are interrelated and are functions of the rolling conditions. In addition, the wear of the rolls was studied as a function of type of drive, roll-neck friction, properties of the strip, and influence of the roll material.—T.G.

Algoma's 46-in blooming and plate mill J. L. Laidlaw (*Iron Steel Eng.*, 1961, **38**, Jan., 67–77) The mill is designed for the production of slabs for plate production, blooms for re-rolling in other mills, beam blanks for a 30-in standard structural mill, and a 50-in universal beam mill, tube rounds (7–10in dia.) sheared plate 104-in wide (¼–⅜in thick, up to 80 ft long) mill produced from slabs previously rolled and heavy plate > ⅜in for flame-cut finishing. The layout is shown and detail of the processes are summarized.—C.V.

Startup and operation J. H. Walshaw (*Iron Steel Eng.*, 1961, **38**, Jan., 74–77) The commencement of production at the Algoma's 46-in bloom and plate mill is described.—C.V.

Experimental rolling of cast slabs of St 3 kp steel on the 810 mill F. D. Ivanov (*Stal'*, 1961, (1), 57) A note from Novosibirsk. Increased temp. and heating time and increased reduction in the first two passes eliminates blowholes. Non-metallic inclusions were present though other defects were removed.

Recent development of light gauge steel structures in Japan T. Naka and T. Kato (*Proc. Symp. on weightsaving of bridges and structures, Japan Soc. Promotion of Science*, 1960, March, 74–85) [In English] Sections and their mechanical properties are considered (16 refs).

Rolling of free-cutting steel into square sections P. P. Zuev (*Iron Coal Trades Rev.*, 1960, **181**, Sept. 2, 537; from *Metallurg.*, 1960, April, 30–31) It was originally the practice at the Elektrostal works during the rolling of R–18 free-cutting steel to use a diamond-diamond roll pass design on the roughing stand and a diamond-square system on the finishing train. During the rolling of the stock at this stage no further work was done as with the decrease in the section of the stock the corners became sharper; this led to a cooling and a sharp drop in plasticity and it was found that a considerable amount of scrap resulted from corner cracking. Later, intermediate heating was introduced and in the first stand of the finishing train, the diamond and square passes were replaced by a flat box and round pass respectively. Rolling was completed within the plastic temp. range of free-cutting R–18 steel (950–900°) and the square section was produced without corner cracks, but there was an increase in metal losses due to scale and in the thickness of the decarburized layer; blunted corners also resulted. In a further development these disadvantages were overcome; this is a combination of the systems using diamond-diamond-oval-round-diamond-diamond. The corners which had previously cooled were displaced first to the sides of the oval, then to the top and bottom of the round, and on delivery to the following diamond pass the corners are formed at different points.—C. V.

American Steel & Wire's newest rod mill R. R. Snow (*Reg. Tech. Meet. AISI*, 1958, 51–60) This mill was designed to replace a billet mill, a continuous three-line rod mill, and a single line coarse rod mill. The billet yard has a capacity of 58 700 tons, $3\frac{1}{4}\times3\frac{1}{4}$in × 30 ft billets; 34 ft can be accommodated. Mechanical separating and feeding to the furnace is described. The furnace can use natural gas, coke-oven gas, or oil and the discharge unit has a capacity of 100 t/h. The mill proper is a four-line mill of 23 stands used for finishing coarse rods; max. finishing speed 6 000 ft/min. The roughing unit and finishing mill and the various problems arising are indicated and discussed and the production achieved is indicated. It is shown that speeds of 6 000 ft/min are practical and with the trend towards heavier weight coils it is probable that higher speeds will be attempted. The possibility of using five lines is also considered while the use of heavier weight rod coils is reasonable; this is being done on a small scale by welding of rod coils but the expense and difficulty in high tonnage production is still a problem. Welding billets or heavier weight billets are alternatives so as to obtain heavier weight coils.—C. V.

Carbon steel sheets (*AISI Steel Prod. Man.*, 1960, Dec., pp.112) A review of production, composition, properties, coatings, and tolerances.

Design details of a new plate mill K. Loeck (*Hüttenwerk Oberhausen, Tech. Ber.*, 1955–58, paper 29; reprint from '*Blech*', 1958, Jan., 17–23) Design and arrangement of the new plate mill that has been in operation since the end of 1957 are described and discussed. The main item is a reversing four-high hot-rolling stand of 3 300 mm face length. This stand is described in detail, followed by descriptions of the ancillaries.—T. G.

Making and treating alloy steel plates R. R. Fayles (*Reg. Tech. Meet. AISI*, 1958, 433–447) The following are considered to be the major factors in producing alloy plate steels: (1) A sufficiently high C at first test to permit a good heat workout prior to tap (0·6% when making grades that require 0·12% at tap); (2) slag oxide should attain levels of 15–18%FeO with a lime–silica ratio 2·8; (3) Bath temp. must be controlled to avoid excessive pouring temp. Slab rolling and slab conditioning are briefly reviewed. The problem of oxide or rolled-in scale is one of the most difficult and persistent problems in connexion with plate rolling. This is primarily connected with the Ni and Ni–Cr types. The scale formed during heating is tenacious and not brittle as in C-steels; its capacity for stretching and bending makes removal very difficult. The various methods of dealing with this are discussed. The ultimate goal is the heating of alloy slabs without forming scale, and special atmospheres or electric heating are possible but cost may be prohibitive. Another approach is a coating on the steel and various ceramics etc. are reviewed. The final finishing processes are outlined.

The conditions for producing thin hot-rolled annealed sheet from U9–U9A tool steel satisfying GOST 3680-57 specification for working F. C. Ivanov (*Stal'*, 1961, (1), 57) A note from Novosibirsk. Seventeen modifications were tried to reduce warping. The main cause of this is non-uniform roll wear and cooling of rolls by high-pressure water, and strip flattening on a smoothing stand improves the material.

The quality assessment of rolled thin and thick oxygen-steel plate G. de Witte (*Metalen*, 1961, **16**, Feb. 28, 56–63) This is a paper read on Feb. 2 before the Metals Section of the Bond voor Materialkennis. It discusses in detail the relative merits of OH and oxygen-steel as regards their mechanical properties, weldability, coatability, and appearance, on the basis of numerous such tests conducted on suitable samples of these steels. Many graphs illustrating the comparative test results appear in the test.—F. R. H.

Conference on the rating of mill type motors (*BISRA Plant Eng. Division, 6th Conf.*, 1951, June, pp.83). **Rating of intermittently-running machinery** H. H. Broughton (3–11). **Power losses, heating and commutation as affecting the choice of mill type motors** A. Tustin (12–16, discussion 17–20). **Some considerations of modern mill type motor design for auxiliary duty** A. G. Williamson and J. H. Messenger (21–26, discussion 27–29). **The selection of series motors and gear box ratios for live roller tables** J. Guthrie (30–36, discussion 36–38). **Factors affecting the choice, design and performance of mill auxiliary motors** W. J. Pool (39–44, discussion 44–47). **The matching of mill type motors to crane duties** G. V. Sadler (48–54, discussion 55–57). **The matching of D.C. mill type motors to their duties in cranes and for mill auxiliaries** H. Nielsen (58–61, discussion 61–63). **Modern trends in A.C. drives for steelworks duties** H. du V. Ashcroft (64–67, discussion 67–70).

Magnetic amplifier in cold rolling mill drives E. Fiebig (*Blech*, 1961, **8**, Feb., 92–96) The characteristics of magnetic amplifiers are compared with electronic amplifiers, determining the possibilities of applying magnetic amplifiers in cold-rolling mill driving mechanisms.—M. L.

Electrical measurements of the drive in the blooming mill of the NHKG V. Pokorný (*Hutn. Listy*, 1961, **16,** Feb., 113–120) [In Czech] methods of electrical measurement in blooming mills are described. At the same time results are given of measuring the main drive in the blooming mill and its necessary drives in the NHKG. The author suggests adaptations to increase the production of the roll stand.

Control of asynchronous rolling mill motors by means of voltage relays V. Pokorný (*Hutn. Listy*, 1961, **16**, (1), 28–30) [In Czech] Methods for achieving improved control, and of setting the relays are discussed.—P. F.

Shear output tripled by sheet handling system (*Metalw. Prod.*, 1961, **105**, March 29, 56–58) It is pointed out that shears operate less than 1% of the time. Time studies have shown that this results from time spent on selecting, transporting, layout-out, and measuring sheet and plate, in moving and position ing material at the shear, and picking up and stacking the finished pieces. A system greatly accelerating the process is described.—C. V.

Fillet rolling W. Egger and G. X. Diamond (*Mach. Design*, 1961, **33**, Jan. 5, 112–119) After a comparison of the general effects of shot peening and fillet rolling, the fillet-rolling process for strengthening shafts, and particularly the fillets of engine crankshafts, is described, and the factors affecting surface finish of fillet-rolled parts discussed, with tabulated data on work hardenability of steel, Al, and Mg. Stellite or carbide rollers as a means of fillet rolling at high hardness levels are suggested.—S. H.-S.

Remote position control (*BISRA Summary* 145, pp.2, 1959, Oct.) An account of the 'translator' for controlling screw-down and position control is given.

Measurement and control of thicknesses, densities and weight per unit area by means of radio-isotopes L. Wiesner (*Technica*, 1960, **9,** Nov. 4, 1433–1438) Physical principles of the radio-isotope method for determining and controlling the thickness, density, and weight per unit area are discussed and criteria for choosing the correct source are given. Construction, layout, and operation of the apparatus are dealt with and applications described.—R. P.

Unevenness of production and dispatching of rolled stock F. Krejčí (*Hutn. Listy*, 1961, **16,** March, 171–174).

Causes of the formation of blow-holes in cold-rolled sheets of grade 08Kp steel F. A. Ksenzuk and N. A. Troshchenkov (*Stal'*, 1961, (3), 274–276) Conditions of pickling and teeming were examined and the appearance of elongated blow-holes in rolled material on annealing was traced to siliceous inclusions. The use of high-grade refractories in bottom pouring reduces rejects greatly.

MACHINERY AND SERVICES FOR IRON AND STEELPLANT

Electrical plant for steelworks during 1960 (*Iron Steel*, 1961, **34,** March, 108–110) A concluding report of a previous contribution (*ibid.*, Jan.).—C. V.

Water in metallurgy P. Boisson and Y. Martin (*Ann. Mines*, 1961, **166**, March, 133–152) Metallurgy in Eastern France consumes annually 10^7 t of coke, 3×10^7 t of iron ore, and 10^9 m^3 of water. The actual consumption is often unknown. After analysing various elements of the cost, and stressing many points where economies might be exercised, the authors advocate general adoption of a closed circuit, viz. reutilizing the water after purification and cooling, as being now installed in new works at Dunkerque.—S.H.-S.

Conference on steelworks electric overhead travelling cranes (*BISRA publication, Harrogate* 1955, Oct., pp.56). **Steelworks requirements for cranes** K. Paterson (5–7). **Manufacturer's views on steelworks cranes** J. Baker (7–15). **Structural design** J. S. Terrington and D. Buchanan (15–23). **Some mechanical maintenance troubles on long-travel drives** I. Scott-Maxwell and C. E. H. Morris (24–40). **Developments in crane controls and motor drive** L. N. Bramley (40–42). **The electrical equipment of steelworks cranes** R. A. West (42—51). **Safety considerations in the design, operation and maintenance of overhead travelling cranes** H. Eccles and H. Entwistle (51–54).

Conference on works transport (*BISRA, report, Sheffield and Rotherham*, 1956, July, pp.55). **Road transport in a special-steel works: advantages of the mechanical shunter and tractor trailer system over the locomotive** J. Walker (5–11). **Road transport at Park Gate iron and steel works** W. D. Allen (11–15). **The internal transport system at the Creusot works in France** M. Gressier (15–22). **Bulk handling by road in iron and steel works** N. W. G. Dolling, A. J. Harby, and C. Hulme (30–44). **British road services transport of finished and semi-finished steel products** H. Elliott (44–46). **Road transport of finished and semi-finished products from iron and steelworks** S. C. Bond (46–52) Including general discussion.

WELDING AND FLAME CUTTING

Are welding codes outdated? R. Weck (*Iron Age*, 1961, **187,** March 16, 109–112) Evidence is presented endeavouring to justify a realistic reappraisal of the entire system of welding codes at present operative in Britain, with comparisons of stress requirements in Germany, Sweden, Holland, France, and USA.—S.H.-S.

Pressure butt welding of steel pipe using induction heating S. G. Harris (*Weld. J.*, 1961, **40,** Feb., 57s–65s) Very rapid welding of steel pipe may be effected in this way. The metallurgical and mechanical aspects of the process are discussed here.

Nippon Kokan's electric fusion weld pipe mill (*Far East Iron Steel Rep.*, 1960, **69**, Oct., 12–13) [In English] Details are given of the U–O press forming and cold expanding plant, built by Kaiser Steel Corp., pipes of od 16–40in, wall thickness ¼–½in, and length 40 ft max. are made at a rate of 100000 tonnes/year.—K.E.J.

High tensile steel girders for Melbourne Bridge Johns and Waygood Ltd (*Austr. Mech. Eng.*, 1961, **48**, Jan. 5, 22–26) The welding of BSS.968 is specially discussed and the submerged arc process using EMF and Lincoln machines with Murex fluxes and wires were used; runs up to 160 ft had to be produced at one pass. The main difficulty anticipated was underbead cracking and this was overcome by preheating to 150–200°; propane fuel gas was first used but the products of combustion condensed on the cold steel and gave rise to imperfect welds; an oxy-acetylene heating torch was subsequently used. Buckling of the webs due to preheating and its prevention is discussed. The essential details of fabrication are given.—C.V.

Equipment for the protection of the underside of welds in the shielded argon-arc welding of stainless steels J. Voděra (*Zváranie*, 1961, **10**, (1), 25–27) [In Czech] Various methods of protecting the undersides by means of a cushion of argon are discussed.—P.F.

Welding in transport industry R. Gosh and A. K. Gupta (*TISCO*, 1961, **8**, Jan., 45–56) The American Welding Society's 'Master Chart of Welding Processes' is reproduced together with their layout showing the historical development of arc welding. A general discussion based on these follows.

Arc welding of galvanized steels M. Puech (*Acier Stahl Steel*, 1960, **25**, Dec., 523–528) Trial joints of various kinds are shown. Zinc paint, Zn–Cd alloy applied hot, or sprayed zinc coating was used and corrosion tests were made.

Welding of precipitation-hardening corrosion resisting steels J. I. Morley and J. A. McWilliam (*Brit. Weld. J.*, 1960, **7**, Oct., 651–658) The compositions, heat-treatment, physical and mechanical properties, and weldability by metal-arc, argon-arc, inert-gas metal-arc, and resistance welding processes are dealt with. The mechanical properties of various welds and the effect of various post-weld heat-treatments are given.

How to weld graphitic tool steel C. A. Pfouts and C. F. Jatezak (*Steel*, 1960, **147**, Nov. 14, 116–117) Three advantages suggested to the user are that tool design may be changed frequently, assembly and heat-treatment errors can be rectified quickly, and, thirdly, worn and broken dies made of weldable tool steel are easier to repair than other types. Basic rules for welding different types of graphitic tool steels are tabulated, and materials are recommended.—S.H.-S.

Welding nickel-free austenitic utility steels of the CrMnN type in protective atmospheres K. Löbl and A. Kabrhel (*Zváranie*, 1960, **9**, (10), 286–290) The development of welding technology for the steels, which contain 0·1%C, 0·2–1·7%Ni, 16–8–17·7%Cr, and 0·27–0·35% N is discussed. Details of the argon-arc method found suitable are given.—P.F.

The problem of welding high temperature service materials C. Kauhausen, P. Kaesmacher, and S. Sadowski (*Brit. Weld. J.*, 1960, **7**, Dec., 693–707) The welding of ferritic steels with 1·0–9·0%Cr and 0·5–1·0%Mo; of 12%Cr steels; of fully austenitic stabilized steels; and the possibility of welding austenitic and ferritic steels with nickel alloy electrodes are discussed.

Repair of cast steel by welding S. Lundin (*ESAB Rev.*, 1960, No.2, 8–14) The operation of welding either ordinary carbon or low-alloy or high-alloy steel is briefly described and illustrated.—S.H.-S.

Higher-strength steels for welded structures R. D. Stout (*Weld. J.*, 1960, **39**, July, 273s–283s) The principles of steel selection are discussed, and the range of properties available from suitable steels, the effects of cold work, strain ageing, and elevated temp. are considered. Weldability characteristics are also treated.

Induction pressure welding of girth joints in steel pipes R. L. Koppenhofer, W. J. Lewis, G. E. Faulkner, P. J. Rieppel, and H. C. Cook (*Weld. J.*, 1960, **39**, July, 685–691) A mechanized process for welding petroleum pipe-lines has been developed. The method is given, and testing procedures on the basis of API specifications are discussed.

Continuous buttweld mill modernizes pipe-making (*Steel*, 1960, **147**, Dec. 12, 86) The mill and its equipment, operation, and results are described.—S.H.-S.

The repair of worn and broken parts. III S. D. Scorer (*Steam Eng.*, 1960, **30**, Dec., 99–102) Various examples of welding and stitching are shown.

Use of welding in chemical plants in the U.K.A.E.A. F. S. Dickinson and B. Watkins (*Brit. Weld. J.*, 1960, **7**, Oct., 643–651) The welding of 18%Cr–13%Ni–Nb steels, Monel, and Inconel is described, and the special problems that occur in this application are treated.

Welding in the production of marine oil engines J. A. Dorrat (*Brit. Weld. J.*, 1961, **8**, Jan., 10–17) The effect of the introduction of machine welding is discussed. The effect of materials, design, edge preparation, and assembly on planning of engine construction is described, and their relation to service conditions considered.

Welders work with many arcs from single power source Consolidated Edison Corp. (*Iron Age*, 1960, **186**, Nov. 24, 96–97) Multi-arc welding, with high production and economy is discussed, with tack welding, stud welding, arc air gouging, and inert arc welding as further developments. Some of the advantages are presented.—S.H.-S.

Whither electrode design? I. C. Fitch (*Brit. Weld. J.*, 1960, **7**, Oct., 600–604) The paper considers the reactions in the welding arc and some of the problems of measuring them. Progress in the design of alloy steel electrodes is considered. The problems of moisture pick-up by low hydrogen electrode coatings and future developments of electrodes with coatings loaded with alloys and iron powder are discussed.

Iron–nickel electrodes for the cold welding of high-strength and grey pig iron G. N. Larin, V. V. Bazhenov, and L. M. Yarovinskii (*Lit. Proizv.*, 1958, (10), 5–8) Fe–Ni electrodes ensure the absence of crystallization cracks in seams and heat-affected zones, satisfactory mechanical workability, and high strength of the welded joint (for high-strength pig iron not less than 40 kg/mm²).—A.I.P.

Steel electrodes containing Ni for welding ships' plates C. Vollers (*Metalen*, 1961, **16**, Jan. 16, 11–12) This article refers to one which appeared in the Philips' house journal 'Techniek en Toepassing', 1960, (5), pp.18 describing artificial sea-water tests on ships' plates welded with various types of electrodes containing Si, Ni, and Cu. Promising results were obtained with the Ni-steel electrodes. The investigation was conducted in view of the increasing navigation and the use of ice-breakers in polar regions since the war where ships' plates become more liable to exposure to sea water through removal of the protective coating usually provided.—F.R.H.

Vickers' aircraft engineers adopt iron-powder electrodes D. M. Jones (*Lastechniek*, 1960, **26**, Nov., 224–226) [In English] The article describes the general change-over from riveted and bolted steel sections for aircraft jigs to metal arc welding using C23 iron-powdered electrodes which resulted in an increased production speed of 50–60% over that of the older method. There are altogether 11 illustrations in the text showing several parts of aircraft fuselages in course of construction.

Electrode for spatter-free welding of steel in carbon dioxide E. Cushman (*Weld. J.*, 1960, **40**, Jan., 14s–21s) A new welding wire is described for CO_2-shielded metal-arc welding of mild steel without weld spatter, which also makes unnecessary the rigid control of arc length formerly required for this purpose. The equipment, process, and results of the operation are presented and discussed.—S.H.-S.

The effect of moisture absorption on unalloyed lime-base welding electrodes and means for reducing the absorption E. Kauhausen and S. Sadowski (*Schweisstechn.*, 1960, **14**, Nov., 121–126) The behaviour of conventional covering materials for welding electrodes in air of high humidity was studied and the effects of water absorption by lime-base electrode coatings on welding practice are described. Means for reducing the absorption of water by the electrode coatings are described and discussed.

How to choose the right shielding gas I. D. Holster (*Steel*, 1960, **147**, Dec. 12, 78–81) A review of shielding gases for consumable (Mig) or non-consumable (Tig) electrode processes, with some case histories.—S.H.-S.

Current welding research problems (*Weld. J.*, 1960, **39**, Dec., 547s–552s) A list of some of the more important research problems facing the welding industry, classified under 12 main groups, which are subdivided into numerous varieties, is presented, supplemented by a call from the Welding Research Council in New York for offers from university professors to investigate any of the problems listed.

Fundamental researches on plasma jet and its application (Report 2). On the characteristics of plasma jet and air plasma cutting M. Okada and H. Maruo (*Osaka Univ., Fac. Eng. Techn. Rep.*, 1960, **10**, Oct., 579–591) Various fundamental characteristics of plasma jets including electric characteristics of the A-stabilized plasma jet and distribution of gas pressure inside the plasma jet device have been investigated. On the basis of these results, an air plasma jet device has been developed, in which air is to be made use of as a plasma working gas. In the application for cutting of industrial materials, many high potentialities of the new air plasma jet have been demonstrated, and therefore it would be expected to form the ideal cutting device in the near future.

Quality in welding E. Fuchs (*Brit. Weld. J.*, 1961, **8**, Jan., 4–9) The author discusses the quality of weld metal, using pipes as an example, and shows how present practice is often wasteful. He then considers design problems, and the way in which costly weld metal consumption can be cut down by good design.

The quality of electroslag welds with different conditions of treatment I. Wachtmeister (*Svetsaren*, 1960, **25**, (2), 25–39) The influence of postweld treatment on structure is discussed (10 refs).

Evaluation of weld quality on a submarine pipe line P. W. Turner (*Weld. J.*, 1960, **39**, Dec. 1215–1221) The inspection of welding on a 30-in dia. submarine pipe-line built in Iran for crude oil service in the Persian Gulf, design requirements, and method of installation, welding, and radiography procedures, and measures used to control weld quality are presented in detail. Every weld was X-rayed and statistical quality control chart method of analysis was used. Types of defects and their causes are discussed.—S.H.-S.

Technical control of welding in the steel foundry M. G. Hipkins (*Found. Trade J.*, 1961, **110**, Jan. 5, 3–7) After indicating the two-fold role of welding, repair of defects, and fabrication of composite structures, the need for training of welding operators is stressed, the various stages in carrying out welding repair or cast/weld fabrication are discussed, and notes are included on the various welding processes available.—S.H.-S.

Weldability of ultra-high strength steels W. A. Sipes and E. F. Deesing (*ONR*–5, **2**, *PB* 161471, 656–671) Work has been done on AISI 4340 steel, and on Vascojet 1000, which is representative of the AISI H–11 type steels. In the first case, an electrode has been developed that gives 100% joint efficiency and a comparable impact strength for base and weld-metal at 285000 psi. In the second case, the work indicates that electrodes are available to give 100% joint efficiency, and similar impact properties at 300000 psi.

Weldability tests as a guide to service performance of weldments R. D. Stout (*Reg. Tech. Meet. AISI*, 1958, 169–189) Longitudinal-bead notch-bend tests can furnish useful information on the influence of steel composition, welding conditions, and thermal and mechanical treatment on the notch toughness of welded steels. It is found that welding lowers the notch toughness of steel by triggering an area for brittle fracture but in addition

to the stress-raising action of geometrical discontinuities, welding can change the base metal near the weld metallurgically; this can introduce notch-sensitive regions in the vicinity of the welded joint. These weldability tests are unsuitable for predicting the service performance of welded engineering structures; they do, however, assist in the control of fabrication conditions so as to ensure that a satisfactory welded structure is obtained.

Cracking tests for assessing weldability J. C. Borland (*Brit. Weld. J.*, 1960, **7**, Oct., 623–637) The paper reviews the many types of cracking test that have been devised to assess weldability, and discusses their characteristics and limitations. Details of each test described are given in an appendix (60 refs).

Thermal fatigue of the welded joint of an exhaust manifold S. I. Kutkovskii (*Lit. Proizv.*, 1958, (10), 38) Two methods of repairing the welded joint are described. The more simple method is recommended for ensuring the hermetical sealing of the manifold. It consists of the welding up of the drainage aperture of the cover. When this is done, cracks spread slowly, and are limited in extent.—A.I.P.

Welded cryogenic steel takes impact, pressure J. T. Horton and W. T. Lankford, jun. (*Steel*, 1960, **147**, Nov. 7, 108–109) Tests showing 9%Ni steel can take pressure and impact loading at −320°F, without stress relief after welding, are discussed.—S.H.-S.

Distribution of phosphorus and sulphur in fully austenitic stainless steel welds S. M. Makin, C. B. Alcock, D. R. Arkell, and P. C. L. Pfeil (*Brit. Weld. J.*, 1960, **7**, Oct., 595–599) By addition of small amounts of radioactive phosphorus and sulphur to a 24%Cr–21%Ni steel, which was subsequently fabricated in thin sheets and used for welding trials, it was possible to trace the concentration of these elements in the welds. It was found that P segregated preferentially in some areas, while S did not: it is suggested that P is important in the hot-cracking of fully austenitic stainless steel welds.

Notch-rupture strength of type 347 heat-affected zone R. J. Christoffel (*Weld. J.*, 1960, **39**, July, 315s–320s) It was found that, as-welded, this steel showed a seriously impaired notch-rupture heat-affected zone. By post-weld heat-treatment this loss of strength could be eliminated. Such a heat-treatment is thus always advisable. The reasons for the loss of strength are discussed.

Types and causes of distortion in welded steel and corrective methods O. W. Blodgett (*Weld. J.*, 1960, **39**, July, 692–697) Various sorts of joints, the distortions they may tend to produce, and measures to prevent these are surveyed.

Hydrogen in welding P. G. Bastien (*Brit. Weld. J.*, 1960, **7**, Sept., 546–557) The sources and effects of H_2 in the welding of cast, welded, and wrought steels are discussed. The present state of knowledge in this field is stated, and some unsolved questions are presented (36 refs).

Discussion at the Symposium on fatigue of welded structures (*Brit. Weld. J.*, 1960, **7**, Aug., 513–537) The following papers were discussed: Influence of weld details on the fatigue strengths of welded beams and girders, by W. H. Munse and J. E. Stallmeyer. Programmed fatigue testing of full-size welded steel structural assemblies, by J. G. Whitman and J. F. Alder. The fatigue strength of fillet welded joints in steel, by T. R. Gurney. A systematization of the fatigue strength values of mild steel welds, by A. Neumann.

Effect of boron on tendency of high-strength austenitic steels type 1Kh13N18V2B to hot-crack formation during welding A. V. Russiyan and M. Kh. Shorshorov (*Lit. Proizv.*, 1958, (10), 14–18) An increase in B content from 0 to 0·015% decreases the temp. of a sharp drop in ductility in the heat-affected zone from 1150 to 1010° and increases the brittle temp. range as a result of the separation of B-containing structures along the grain boundaries under conditions of welding with rapid heating.

Analytical investigation of residual stresses and distortions due to welding K. Masubuchi (*Weld. J.*, 1960, **39**, Dec., 525s–537s) The fundamental principles of a theory aimed at developing a method of analysis similar to Prandtl's wing theory in aerodynamics, to study residual stresses in a welded plate, are mathematically described in this paper and a summary of the results is presented.—S.H.-S.

Generalized theory of super-solidus cracking in welds (and castings) J. C. Borland (*Brit. Weld. J.*, 1960, **7**, Aug., 508–512) The present position with regard to the factors that affect super-solidus cracking is outlined, and the scope for future work is mentioned (22 refs).

High frequency induction brazing of small components in argon streams P. M. Bartle and J. G. Young (*Brit. Weld. J.*, 1960, **7**, Oct., 638–642) Work on the joining of copper, mild steel and stabilized and unstabilized stainless steel tube to Ti and stabilized stainless steel sheet is described.

Joining of metals by special cement A. B. Reifer (*Instrument Construction*, 1959, May, 24–25; from *Brit. Rail. Monthly Rev. Techn. Lit.*, 1961, **11**, Jan. 11) In order to decrease the cost of production of press dies, and the repair of worn tools by the addition of new material, tests were made to determine whether the metal could be joined by cementing. A special plastic cement based on epoxy resin was used. Results are given of experiments with cutting tips cemented to the tool blanks with steel, and brass bushes cemented into steel housings and with the thin working parts of a punching die cemented to a mild steel base. In all cases the cement proved satisfactory and certain advantages are claimed compared with normal practice. R.S.F.C.

New jobs sought for brazing platens AVCO Corp. (*Steel*, 1960, **147**, Dec. 19, 106–107) From use in the honeycomb field, unitized tooling and ceramic brazing is being extended to more complex configurations, a variety of which are suggested. The operation is described and new data presented.—S.H.-S.

Practical aspects of furnace brazing in exothermic atmospheres O. Morávek (*Zváranie*, 1960, **9**, (12), 357–362) Industrial copper brazing of steel parts is discussed. Several specific examples are considered. Brazing takes place in a furnace heated by a town-gas/air mixture. The process is continuous, a conveyor transporting metal components to be brazed through the furnace. The process is considered to be particularly economical in series production.—P.F.

New alloys for brazing heat-resisting alloys W. Feduska (*Weld. J.*, 1960, **39**, July, 292s–300s) The purposes for which new brazing alloys are required are discussed, and the theory behind the development of such alloys is given. The various alloys that have been developed are shown, and the results obtained with them are discussed.

Development of structural and metallurgical requirements for welded hulls R. T. Young (*Brit. Weld. J.*, 1961, **8**, Feb., 43–49) The author outlines the history of welded ships and the incidence of cracking in some ships. The course of the investigations into these failures, and the development of design and material specifications based on this work, are discussed.

Quality control of resistance welds in thin sheet M. Lipa (*Zváranie*, 1961, **10**, (2), 37–42) [In Slovak] A survey is made of the various practices of testing resistance welds in sheet.

Testing the flame weldability of thin steel sheet M. Bašista (*Zváranie*, 1961, **10**, (2), 34–37) [In Czech] Experimental work and extensive experience in welding have led the author to propose a set of tests of weldability for standardization. The tests are readily carried out in practice and should find acceptance with welders.—P.F.

Microstructure and mechanical properties of weld joints of austenitic and ferritic–pearlitic creep-resisting steels for boilers with high parameters K. Pawera, V. Pilous, and F. Pobořil (*Hutn. Listy*, 1961, **16**, March, 186–197) Argon-arc welding with special electrodes is described. Tests of creep and thermal fatigue as well as metallographic examination were carried out. Corrosion testing in condensates saturated with O_2 and CO_2 was also applied.

A new hypothesis on hydrogen in weld pores L. Lakatoš (*Zváranie*, 1961, **10**, (1), 29–30) [In Slovak] Recent Polish work on H_2 in welds is discussed. H_2 may enter welds due to its reaction with C, Si, or S. On welding with electrodes having acid or rutile coatings, from which the removal of H_2 is difficult, the C, Si, and S contents induce considerable pore formation. On welding with basic electrodes, pore formation can be minimized by annealing the electrodes carefully. Mn and P (up to 0·2%) are not responsible for the formation of pores in welds.

The nature of the diffusion of brazing alloy elements into heat-resisting alloys W. Feduska (*Weld. J.*, 1961, **40**, Feb., 81s–89s) A microstructure and microhardness study was made of the diffusion of single and binary combinations of elements, present in commercial high-temp. brazing alloys, into heat-resisting alloys. Data obtained on 105 diffusion samples isolated the effects of individual diffuser elements during brazing alloy base metal interface reactions.

Vacuum brazing V. Horáček (*Zváranie*, 1961, **10**, (1), 14–17) [In Slovak] Vacuum brazing is discussed, with special reference to the utilization of a new type of Czechoslovak vacuum furnace capable of developing temp. up to 1400°C.—P.F.

On the present position of adhesive bonding for metals H. Winter and H. Meckelburg (*Metall*, 1961, **15**, March, 187–199) Fundamental principles of adhesive bonding of metals are discussed as well as the nature of the adhesive/metal bond. The method of bonding is described, followed by a discussion of the mechanical properties and corrosion behaviour of the bond. Methods of testing the bond, design principles, and possible applications of adhesive bonding of metals are dealt with (64 refs).—R.P.

The mechanics of adhesive bonding N. K. Benson (*Appl. Mech. Rev.*, 1961, **14**, Feb., 83–87) A survey of the analytical and practical aspects of adhesive bonding, with structural applications and some current problems, is presented.—S.H.-S.

Multi-head flame cutter clips cost (*Metalw. Prod.*, 1961, **105**, March 29, 54–55) Scammell Lorries Ltd, Watford, have installed a multi-head Hancoline electronic cutting machine; template costs are cut by 50% and up to four times the output of flame cut parts has resulted.—C.V.

Efficient utilization of blanks in cutting round plates with the oxygen torch J. Voděra (*Zváranie*, 1961, **10**, (2), 47–48) [In Czech] It is shown that considerable economies can accrue in repair and maintenance work if, in oxygen cutting of circular pieces, attention is paid to the possible utilization of the remainders of the blank.—P.F.

Heavy-duty constricted tungsten-arc cutting of all metals W. A. Geideman and H. B. Bott (*Weld. J.*, 1961, **40**, Feb., 132–140) The improvements in this method of cutting allow of 4in high-quality cuts in stainless steel.

MACHINING AND MACHINABILITY

How to avoid common machining errors E. J. Krabacher (*Steel*, 1961, **148**, March 20, 96–99) Opinions of seven machining experts on methods of increasing machining efficiency are presented.—S.H.-S.

What we should know about cutting fluids (*Usine Nouv.*, 1961, **17**, Feb. 16, 35–37) [In French] The purpose and action of cutting fluids are described. The applications and advantages of the most common of these oil-base fluids, water-base fluids, soluble oils, transparent solutions, and synthetic products are briefly described.

Study for the preparation of work in the rolling department of a machine shop: design, marking, and storage of tools J. J. Fernandez Fernandez (*Met. Elect.*, 1961, **25**, Feb., 86–88) A system of tool classification is presented with a colour scheme and symbols giving an instantaneous key to the uses for which they are intended.

Analytical cutting-tool design Chance Vought Aircraft Inc. (*Eng. Digest*, 1961, **22**, Jan., 73–78) Based on the investigations by Chance Vought Aircraft the importance of the effective rake angle α_e in determining optimum cutting-tool geometry is examined and discussed. In some cases spectacular results have been obtained. It is considered that if the

techniques reported on are used, it becomes relatively simple to determine this geometry directly for most cutting operations and work-piece materials.—C.V.

Ceramic tools and lathe finishing of steel pieces (*Usine Nouv.*, 1961, **17**, March 9, 33–34 [In French] Tests are described to find the best conditions for using ceramic tools in lathe finishing. Aspects dealt with include influence of cutting speed and comparison with carbide tools.

The machining of steel F. C. Lea and E. N. Simons (*Edgar Allen News*, 1961, **40**, Feb., 38–39) This continuation article completes a section on planing and shaping machines, and deals with single-edge cutting tools under the headings of clearance angle, rake angle, tool nomenclature, and modern tool forms. **II. Planing and shaping machines** (Jan., 15–17) A simple explanation of the principles and practice is given. **III. Single-edge cutting tools** (Mar., 58–59) A simple explanation of the principles and practice is given. A chart of cutting tool shapes is provided.—C.V.

The multiplication of current cutting speeds —second report M. Kronenberg (*Werkstättstechnik*, 1961, **51**, March, 133–141) Ultra-high cutting speeds were attained by shooting the work-piece by the side of the tool and along a rifle barrel, or by connecting the tool with a rocket-sleigh which was shot along the work-piece. The tools made of high-speed steel containing 14%W indicated no fissures, breaks, or melting. The surface was satisfactory. The tool wear decreased with increasing speed up to a certain limit—35000 m/min (11 refs).—M.L.

Improvement of machinability by treatment of the liquid melt with nitrogen G. Blanc and N. Volianik (*Fonderie*, 1961, Jan., 3–10) Details are given of the melt treated, the method used, and variables are investigated. Results obtained in presence and in absence of a ferrosilicon inoculant are compared. Machinability is stated to be greatly improved.—R.P.

The present position of the hydraulic and pneumatic equipment of machine tools for sheet working G. Oehler (*Mitt. Forschungsge. Blechverarbeit*, 1960, Nov. 1, (21), 258–271) A detailed review of existing equipment and lines of development.

Transfer line makes better wheels Baldwin-Lima-Hamilton Corp. (*Steel*, 1960, **147**, Oct. 24, 100) A five-machine line, doing boring, facing, and turning operations in sequence, and turning out a finished wheel every 75 sec is described and illustrated.—S.H.-S.

Contributions to the study on the cutting of carbon steels M. P. Popov, I. Mitrica, and E. D. Deciu (*Rev. Méc. Appliq.*, 1960, **5**, (6), 801–819) The paper presents results pertaining to the machinability of some Rumanian carbon steels with the aid of sintered carbide tipped cutting tools.—C.F.C.

The formation of continuous chips in metal cutting W. B. Rice (*Eng. J.*, 1961, **44**, Feb., 41–45) Results of experimental investigations into the formation of continuous chips in metal cutting are presented. Observation of these chips using high-speed photography is described.

Can hot machining techniques keep pace with new alloys? Cincinnati Milling Machine Co. (*Iron Age*, 1961, **187**, March 2, 98–100) Hot machining as a technique for handling new alloys and the use of radiofrequency heat in reducing thermal damage to work, with results, are reported.—S.H.S-.

New developments in the theory of the metal cutting process. I. The ploughing process in metal cutting P. Albrecht (*Trans. ASME J. Eng. Indust.*, 1960, **82**, Nov., 348–358) 'Ploughing' is discussed. This concept makes possible the construction of a more detailed force diagram and serves as a basis for the development of a complete analytical model of the cutting process. A study of the sharpness of cutting tools is presented. The sharpness of the radius has been measured and its influence on the metal-cutting process studied; the technique of this method of sharpness measurement is described. The magnitude of the sharpness radius falls into a range between 0·0001 and 0·001in, the higher values corresponding with the negative range of rake angles and the smallest values were related to high positive angles. A new force diagram, apart from the ploughing forces, shows the forces on the wear land of the took flank; these are small as compared to the shearing or ploughing forces in a freshly ground tool.—C.V.

The machining of hardened steels L. M. Reznitskii (Translation of monograph *Mekhanicheskaya Obrabotka Zakalennykh Stalev*, Moscow/Leningrad, 1958, pp.398; *LC SLA* 60–23865; from *US Techn. Trans.*, 1960, **4**, Nov. 25, 571–572) Data are surveyed under the following chapter headings: (1) Mechanical properties of hardened structural alloy steels; (2) Cermets, hard alloys, and mineral ceramics; (3) Turning of hardened steels; (4) Face milling of hardened steels; (5) The drilling of hardened steels; (6) Finish-reaming of hardened steels; (7) Rose-reaming of hardened steels. (8) Threading of hardened steels; and (9) Discussion of physical phenomena in the machining of hardened steels.—R.S.F.C.

Cutting techniques for stainless steel J. M. Henderson (*Can. Metalw.*, 1960, **23**, Oct., 37–39) The need for sharp tools, slower speeds and increased power for cutting stainless steels is discussed and various methods of their uses presented, including the Guerin process for blanking light-gauge sheets. The cutting of heavy sections economically by oxy-acetylene torch with flux injection, using new equipment which makes cutting stainless steel possible at substantially the same speed as carbon steel, is briefly described.—S.H.-S.

Cutting fluids P. A. Smith, E. L. H. Bastian, and C. A. Sluhan (*Mech. Eng.*, 1960, **82**, Sept., 72–73) A brief review.—C.V.

On the behaviour of abrasive grains in the grinding process H. Tsuwa (*Osaka Univ. Fac. Eng. Techn. Rep.*, 1960, **10**, Oct., 733–743) The behaviour of cutting edges of abrasive grains in a grinding wheel is not sufficiently known. The author has made researches on these matters such as breakage, dig-out, and wear of grains by the observation of the light-section method. From these studies, changes of cutting edges and distance between cutting edges were made clear, and it was shown that the wear of grains was a most important factor in grinding processes (11 refs).—C.F.C.

Fast spinning action removes machining marks General Motors Corp. (*Iron Age*, 1961, **187**, Jan. 12, 60–61) A process, which power-spins odd-shaped automotive parts up to 12in in length through a dry granular compound, such as corn-cob meal, imparting polish, with high production, and without tumbling action, is described and illustrated.—S.H.-S.

Hot machining. 2. Hot milling superalloy boosts tool life Cincinnati Milling Machine Co. (*Metalw. Prodn.*, 1960, **104**, Nov. 30, 58–60) At 1000°F milling improves tool life 20 times with 17–4 Mo and 100 times with Thermold J.

Hot machining . . . which heat source is best? (*Metalw. Prodn.*, 1960, **104**, Dec. 7, 84–87) Flame, induction, furnace, resistance, RF, and arc heating are briefly discussed and compared.—C.V.

Metallurgical effects of hot machining Cincinnati Milling Machine Co. (*Metalw. Prod.*, 1960, **104**, Dec. 21, 60–63) Results of tests made during investigations on the metallurgical effects of hot machining on the refractory alloys and on hardness showed that no detectable change in microstructure occurred, and that tempering was present only when the tempering temp. had been exceeded.—S.H.-S.

CO_2 coolant makes stainless steel behave E. C. Hall (*Metalw. Prod.*, 1960, **104**, Dec. 7, 91–93) This coolant, used in conjunction with special tool geometry, increases output and tool life; for routing the improvement in production on conventional methods is 8:1 and for turning 3:1. Various examples are given. The method of storage and supply is indicated.

Converted machine bores and hones in one set-up H. E. Jackson (*Metalw. Prod.*, 1960, **104**, Dec. 21, 59) The operation of a gun-boring machine, which has been converted to produce bored and honed hydraulic cylinders, boring from one end and, when both operations are needed, honing from the other, is briefly described.—S.H.S.

New Swift high-speed ceramic and carbide tool-testing lathe George Swift & Sons Ltd. (*Machinery*, 1960, **97**, Sept. 21, 675–676) This lathe has a capacity for bars up to 9in dia by 36in long. The spindle is driven by a stretchless timing type belt giving positive transmission, the drive being from a 40 hp variable-speed dc motor which has a range from 400–1600 rpm. There are no gears in the transmission and the spindle speeds (310–5000 rpm) are obtained by interchangeable quick-release taper bore pulleys giving two groups of speeds. The bed is specially designed and the tool-holders slide is provided with power feed rates from 0·00007 to 0·016 and 0·00028 to 0·064in per rev. for the low and high range of spindle speeds. The heavy duty tailstock has a live centre and built-in thermometer while the tailstock barrel has a hydraulic axial-loading system so that a constant pre-set load can be applied during cutting. The hydraulic system operates at a max. 2000 lb/in^2 the load being constantly maintained during cutting despite expansion.—C.V.

Factors affecting the tool wear cutting time relationships for tools J. Taylor (*Machinery*, 1960, **97**, Oct. 12, 853–859) A paper, showing the manner in which tools wear with the passage of cutting time, and how variation can be predicted by applying recent discoveries on metallic wear and friction to the particular case of cutting tools, with important practical applications to be considered.

Turning of high-strength steels in the hardness range of 330 to 560 Brinell C. T. Olofson (*PB* 161208, 1960, July, pp.44; from *US Res. Rep.*, 1960, **34**, Nov. 18, 624) This report contains information and data on the turning of steels of hardness levels up to 560 Brinell. The problems of machining these steels are minimized if rigidity of machine, tool, and work-piece, and adequate power to maintain cutting speed exist throughout cutting. The proper selection of feeds, speeds, and depths of cut appropriate to recommended tool materials and designs are important for adequate tool life and metal removal rates (34 refs).

Operations on components for large marine diesel engines R. E. Green (*Machinery*, 1960, **97**, Oct. 5, 764–774) Some of the methods employed by William Doxford & Sons (Engineers) Ltd are described and illustrated. The production of cylinder liners, the milling of exhaust and inlet ports, the production of crankshafts (operations on crankwebs, double crankpin, and journal components), and the assembly of crankshafts by shrinking are discussed and the final machining, polishing, and inspection are described. Crankpins must be parallel with the shaft axis within $\pm 0{\cdot}1$ mm over their length while the outer pins must be co-axial within $\pm 0{\cdot}5$ mm but it is claimed that a considerably higher degree of accuracy is normally maintained.—C.V.

Have you considered all forms of electrical machining? (*Iron Age*, 1960, **186**, Dec. 8, 115–117) The use of electrical machining whereby plastic deformation in the work material is avoided, is described in three different processes, and their operation and advantages, compared with conventional machining methods, are discussed.—S.H.-S.

Electrochemical machining Metachemical Processes Ltd (*Machinery*, 1961, **98**, Jan. 25, 218–221) The Metachemical electrolytic machining process is based on the principle of electroplating but is carried out at a much higher rate; it can also be adapted for high-speed deposition of metal. Examples of machining and drilling are shown. The Dalic process is also discussed; this enables electrolytic deposition to be performed selectively without the use of a tank of electrolyte. This will deposit metal in a bore which is worn or machined oversize, and can be installed in a production line where it is necessary to provide a bore with a hard coating or with other required properties.

The cold-hobbing of hot working steels W. Haufe (*Machinery*, 1961, **98**, Jan. 11, 70–77) Cold-hobbing is defined and the process outlined the economies being stressed; the example of a hexagon bolt head is given, the time required for sinking each cavity by machining and hand work being 435 min per insert while with the hob this cavity is produced in 240 min. Some 19 examples are shown and details as to steel composition, etc., are given.—C.V.

Economies of cutting processes J. Cherry

(*Prod. Eng.*, 1961, **40**, Feb., 122–138) The economics of automatically controlled machine tools are briefly discussed, followed by a mathematical survey of the economics of the cutting process with nomograms, followed by an appendix on optimum machining conditions, and concluding with a general discussion.

The cutting power expended in the case of carbon steels M. P. Popov, I. Mitrica, and E. Deciu (*Acad. Romine, Studii Cerc. Mec. Aplic.*, 1960, **11**, (6), 1481–1495) The power absorbed in the turning of carbon steels was studied in the case of lathe tools reinforced by metallic carbides, and sharpened to the optimal geometry corresponding to each type of steel. The principal factors influencing the cutting power expended were studied and formulae were developed for calculation of the effective power, which can be applied to practical economic operations.—M.L.

Machine makes smooth cuts in honeycomb materials Dynacor Corp. (*Iron Age*, 1960, **186**, Nov. 17, 141–143) A new machine, cutting slabs from all sizes of stainless steel, and other honeycomb metal logs such as Zr and Ti, and even in many cases, Al in honeycomb form, is presented, and its principles and operation described. A low-voltage high current passes from the cutting tool to the workpiece within a flood of coolant. The resultant arcing disintegrates the metal just ahead of the cutting tool, the coolant removing the heat from the operation, without harm to the material adjacent to the cut, leaving a burr-free surface. The process, an extension of the band-sawing technique, is described with relevant data.

Honing of heading and upsetting dies G. Haasis (*Wire World Int.*, 1961, **3**, Feb., 21–24) An illustrated descriptive article; examples are given.—C.V.

A new method of testing free abrasive particles. I H. Stotko (*Radex Runds.*, 1960, Aug., 203–220) The present state of knowledge in this field is reviewed, and a new method, based on continuous measurement of the grain size and size variation during grinding is described, with details of the equipment and its operation.

Fast cutting with carbon dioxide coolant L. L. Arundel (*Engineering*, 1961, **191**, Feb. 17, 266–267) This affords faster and continuous cutting with longer tool life, improved surface finish, cleaner working, and enables an unobstructed view of the workpiece to be maintained. The cutter body was En24 steel, speed 6000 rpm and a feed of 120 ft/min. Coolant is taken at 1000 lb/in^2 from the line and regulated by capillary size to 15 lb/h. Tool geometry is briefly summarized.—C.V.

The manufacture of steel cylinders of high surface quality and dimensional accuracy H. von Weingraber (*Werkstattstechn.*, 1961, **51**, Jan., 8–12) By the process described, laboratory-scale tests have shown that steel cylinders can be obtained with a high-quality surface finish (a roughness depth of 0·1 μ) and good dimensional accuracy. The special equipment used and its application to the manufacture of precision steel bolts are described.

Practical experience with two- and three-disc lapping machines R. Clar (*Maschinenwelt Elek.*, 1961, **16**, (4), 139–142) In most flat-machined items finishing by fine-polishing is preferred, attaining a surface of coarse texture of depth R max. = 0·3–0·4 μ, while the plane and plane-parallel accuracies are equal to those obtainable with cast lapping discs. The latter must be used in the finishing of very hard materials and Al alloys, as well as in the finishing of those steel parts in which high accuracy is required, R max. = 0·1 μ, and in these cases good pre-polishing must be performed.—M.L.

Lustre- and lapidary-polishing of metal goods H. Curti (*Met. Rein.+Vorbeh.*, 1961, **10**, March, 35) The characteristics and technology of lustre-type polish and the lapidary type polish of metal goods are reviewed, reporting on modern equipment used.—M.L.

Radioisotopes check machining operations J. H. Tolan (*SAE J.*, 1960, Oct., 56, 57) A radioisotope probe is used to detect variations in the contour of a workpiece to 5% at a cross-section ⅛in dia. Other examples of the application of the probe are given which include grinding of threads on a lead screw, checking the concentricity of bored holes and monitoring the position of a cutting tool relative to the work.—A.H.M.

Aluminium in stainless alloy improves machinability Universal-Cyclops Steel Corp. (*Iron Age*, 1961, **187**, March 16, 118–119) A new alloy, Uniloy 303MA, claiming many advantages over AISI Type 303 stainless steel, with improved corrosion resistance, easier machining, longer tool life, smoother finishes, and less longitudinal splitting is presented, with data from four users.—S.H.-S.

Practical and economical problems of machining cavities by spark erosion W. Ullmann and T. G. Traube (*Met. Treatment*, 1960, **27**, Dec., 493–501) The author describes recent advancements in the machining of moulds and dies by the spark erosion method. Machines are described and various examples of complex dies are given. The article is concluded by an economical discussion of electrode production.—A.H.M.

Electrochemical machining Steel Improvement and Forge Co. (*Air Prod.*, 1961, **23**, Feb., 68–72) Developments in the Sifco electroshaping techniques and further applications are reviewed. By this technique, an electrolyte is used to induce a high amperage current to pass between a cathode tool and an anode workpiece; this causes the latter to be electrolytically dissolved. The process is especially suitable for fine work such as small dia. drilling, but it can equally well be used for heavy processes such as forging-die manufacture.—C.V.

Electroshaping: new process speeds metal removal L. Faust and C. A. Snavely (*Iron Age*, 1960, **186**, Nov. 3, 77–80) A method whereby forgings are electroshaped into turbine blades with very close contours, using electrical energy to dislodge the surface atoms of the metal and sweeping them away by a rapid and controlled flow of a chemical solution, is presented. Further developments in other directions are predicted, using similar techniques.

Results of high-energy and ultra-high velocity working of metals E. O. Genzsch (*Maschinenwelt Elek.*, 1961, **16**, Feb., 45–53) High energy methods using explosive, pneumatic, and hydraulic means are compared with conventional tools and loads. Pressures and cutting rates are determined and the properties of all materials and tools used are investigated after shaping. The instruments used are described.—R.P.

CLEANING AND PICKLING

Automatic machine cleans degreaser solvent Detrex Chemical Industries Inc. (*Steel*, 1961, **148**, March 20, 112–113) An automatic filtration system for cleaning solvent, employing diatomaceous earth on a stainless steel, cartridge-type unit, and its operation, are described.

Integrated metal finishing (*Prod. Fin.*, 1960, **13**, Sept., 63–67) The Du Pont Triclene system of pretreatment and painting using trichlorethylene-based media throughout is described, cut-away diagrams being shown; the three main surface treatments are (a) vapour cleaning + non-flammable painting, (b) vapour cleaning + non-aqueous phosphating, (c) vapour cleaning + non-aqueous phosphating + non-flammable painting. The economic advantages are briefly indicated.—C.V.

Cleaning and passivation of stainless steels H. Reinsch (*Met. Rein.+Vorbeh.*, 1961, **10**, March, 33–34) The degreasing, cleaning, and passivation processes for rust-proof steels are reviewed—with special consideration of martensitic and ferritic Cr steels, stabilized and non-stabilized Cr–Ni and Cr–Ni–Mn steels, employing HNO_3 or HNO_3+HF, as well as anodic passivation methods.—M.L.

Descale steel for closer check. Mechanical blaster brings flaws into focus Wheelabrator Corp. (*Iron Age*, 1960, **186**, Nov. 3, 82–83) A method of guarding against flaws in raw material by blast descaling all stock, including carbon steel, stainless steel, tool steel, and Ti products prior to inspection, with resultant economies, is described.—S.H.-S.

Hydraulic forge scale removal installation W. Giesen (*Blech*, 1961, **8**, Feb., 98–104) Forge scale removal is more effective and economical by hydraulic means as compared with mechanical. An installation for forge scale removal from thick sheets before and after hot-rolling, comprising nozzle, high-pressure water pumps, and high-pressure water containers and pipes and controls, is described.—M.L.

Surface treatment of stainless steels G. Colombo (*Acciaio Inossid*, 1961, **27**, (6), 533–535) [In Italian] Surface cleaning and salt base pickling are described.

De-sanding of cylinder-heads with molten caustic soda C. S. Johnson and R. Williams (*Found. Trade J.*, 1961, **110**, March 2, 265–268) The process used at the Farington foundry of Leyland Motors Ltd, is described.—C.V.

Continuous pickling of steel strip (*Wiggin Nickel Alloys*, 1961, (60), 28–29) The plant in operation at the Kembla Works of John Lysaght (Australia) Pty Ltd is briefly described. This uses hot-rolled strips 24–60in wide and the 8 t lengths are joined together by 'stitching' or welding, passed through acid, is washed, dried, side-trimmed, etc. The pickling line is 700 ft long and can handle 70 t steel/h. There are four pickle tanks maintained at 98° and at full speed the acid has only 40 s to remove the scale.—C.V.

A method for predicting solution breakdown of phosphoric acid metal conditioning baths M. H. Swann (*PB* 151431, 1958, Oct. 20, pp.9) A test with monosodium phosphate for predicting exhaustion is developed.

Polishing of steel with a jet of electrolyte E. Yu. Yuganson (*Electropl. Met. Fin.*, 1961, **14**, March, 96–97; from *Mashinostroitel*, 1960, (5), 32–34) An economical method of electropolishing metals developed by the Tallin Scientific Research Institute for Electrical Engineering and now in use at one of the machine building works of the Estonian SSR, is described with data on both apparatus and electrolyte.—S.H.-S.

Shot blast at new Consett mill (*Iron Steel*, 1961, **34**, March, 92–95) A Spencer and Halstead mechanized installation has been installed. This 'Centriblast' plate cleaning and priming plant is designed to shot-blast finished plates when required and coat them with an anti-rust compound or paint as required. Full details are given.—C.V.

Progress in ultrasonics for metal finishing P. Sherwood (*Prod. Fin.*, 1960, **13**, Sept., 76–78) A brief review: A table is given showing the min. time required for each step, the temp. and the conc., the conventional metal surface preparation methods being compared with the use of ultrasonics. With the conventional method, time varied from 2–10 min, temp. 100–212°F, while with ultrasonics the time was 10–30 s at room temp. In general, the concentrations used with this latter method were $\sim$50% of those normally employed.—C.V.

PROTECTIVE COATINGS

Thirty-five years of outplating experience Atlas Plating Works Ltd (*Met. Fin. J.*, 1961, **7**, Jan., 5–10, 18) The subjects covered are the barrel shop, plating and polishing, the methods of drying, lacquering, power supply, and effluent disposal employed in the company's Battersea factory.

Protection of metallic materials against corrosion. I R. Schamschula (*Maschinenwelt Elek.*, 1961, **16**, (3), 111–114) The corrosion resistance of a series of metals is discussed, covering steel, Fe, Al, Zn, Cu, Cr, Pb, Sn, Mg, Ni, Ag, Au, Pt, Ir, Rh, Pd, Os, Ru, Ti, Ta, and Zr and also their performance in different media. The effects of alloying, and of cold and hot working on the properties of some of these metals, as far as corrosion is concerned, are also discussed. **II.** ((4), 143–148) The measures for preliminary treatment of the metallic surface, prior to the actual protective treatment against corrosion, are discussed, covering: the coarse processes, mechanical cleaning, sand-blasting, and mechanical cleaning, sand-blasting, and mechanical polishing, and the fine processes, mainly degreasing, by chemical or physical methods, pickling, and chemical and electrochemical polishing.—M.L.

Effluent treatment for the small plater J. Lakin (*Electropl. Met. Fin.*, 1961, **14**, March, 89–92) A series of arrangements for handling different types of effluent, whether in batch or

continuous flow systems, is non-ferrous pickling. Effluents or mixed chromates and cyanides, are described, and the method of neutralizing and disposing of sludge is discussed.—S.H.-S.

The effect of design on plateability D. N. Layton (*Quality Chromium Plating: Confidence in Plating, Proc. of Symposium, Feb.* 1960, *Birmingham*, 1960, H 1–9) The fact that current-density distribution is not uniform over an article is stressed and the necessary techniques to achieve uniformity are outlined. The role the designer can play is summarized. The shape and positioning of anodes in current-density distribution of differently shaped cathodes and the areas of deposition are illustrated and the improvement in uniformity of the deposition is clearly shown by the reshaping, the re-positioning of the anode, or by the inclusion of burners.—C.V.

The care of plated parts R. J. Brown (*Quality Chromium Plating: Confidence in Plating, Proc. of Symposium, Feb.* 1960, *Birmingham*, 1960, G, pp.9) The necessary precautions are discussed.—C.V.

On the behaviour of 'semi-conducting corrosion protection' under the action of a direct current E. Badum, J. Beckmann, and R. Weintz (*F. & G. Rundsc.*, 1959, July, 149–155) Experimental results are discussed which show that the inhibiting action of a 'semi-conducting corrosion protector' is destroyed by oxidation processes due to electrochemical reactions. Semi-conducting protection for Al sheaths can be used only in the absence of stray currents.—R.P.

Contribution to the question of ventilating plating installations H. Henig (*Metalloberfläche*, 1961, **15**, Feb., 49–51) Theoretical principles and the mathematics of increasing the suction rate by overblowing are discussed, followed by considerations regarding the advantages and limitations of the return-air method.

Disposal of waste from metal-treatment plants (*Met. Fin. J.*, 1961, **7**, Jan., 24–26; Report on the Industrial Effluent Conference, Milan. A report of the various subjects discussed at the Conference, in sufficient detail to indicate the scope of the papers.

The B.N.F. plating gauge S. W. Baier (*Quality Plating Chromium: Confidence in Plating, Proc. of Symposium, Feb.* 1960, *Birmingham*, 1960, D, pp.10) Alternatively, this is called a 'Coatings Thickness Meter'. It uses the same principle as the thermocouple pyrometer and the emf is measured by a millivoltmeter. In the case of the thermo-electric thickness gauge a heated Cu-probe is placed on a piece of steel or iron which is connected by a Cu-wire, thus producing a thermocouple circuit. If a hot steel probe is placed on a piece of steel, no emf results; where a thin layer of Ni is interposed, two voltages will be produced (a) between the steel probe and the Ni and (b) an opposing voltage between the Ni and the underlying steel block. The instrument is illustrated and examples are given of its use.

Calculation of the weight of the deposit, the current density and the time of plating in the electrolytic deposition of metallic coatings K. Müller (*Draht*, 1960, **11**, Aug., 461–462) Equations are given for these quantities, and their use illustrated by examples.

Crack-free chromium plating J. Corbière (*Met. Fin. J.*, 1960, **6**, March, 109–111) The Brown, the self-regulating Stareck, and the crack-free Novochrome solutions all gave good deposits. General observations and testing would appear to show that the Novochrome gave the best results. Additions of In gave no practical improvement in concentrations up to 500 mg/l but Se appeared to have a favourable effect, although more pronounced action was obtained with additions of Sn, Al, V, and Mo; the results obtained with Te, Li, and Cd are doubtful but Sb is unfavourable. Se would seem to produce a change in the crack pattern.

Plating costs tumble sharply on lustrous chrome line G. N. Harrington (*Iron Age*, 1960, **186**, Nov. 10, 184–185) Economic effects in increased production, and better inspection arising from adoption of Bright Ni#66 plating solution plus other operational advantages are presented, with data on equipment.—S.H.-S.

Acceptance requirements for nickel–chromium plating W. G. L. Miller (*Electropl. Metal Fin.*, 1961, **14**, Feb., 40–47) Extracts are given from the Ford Motor Company Ltd specification P–40 showing the application and minimum requirements. Detailed testing and arbitrary tests such as the SO_2 and other tests are discussed.—C.V.

Zinc coatings on iron and steel. A survey. 7. Tests and specifications A. K. Parker (*Met. Fin. J.*, 1960, **6**, Oct., 393–396, 403) Routine tests for thickness (or weight), uniformity, adhesion, and ductility are surveyed and compared. Reservations on accelerated corrosion (laboratory) tests are stressed.—S.H.-S.

Zinc plating of carbonitrided steel L. R. Kohan and H. T. Francis (*Plating*, 1960, **47**, Oct., 1155–1158) Simulated barrel plating trials were carried out to discover the cause of frequent failures in the plating of carbonitrided steel. The cause appeared to be ready re-dissolving of the coating when the article was buried in the mass of parts and not subject to active deposition. No complete answer was found.

Choosing between zinc and cadmium electroplate for corrosion protection of major appliance components S. J. Beyer (*Plating*, 1960, **47**, Dec., 1361–1363) Cd is more ductile than Zn; if the parts have to be formed after plating Cd should be used; Zn will take limited forming. Freshly plated Cd is easier to solder than Zn and Cd plated screws require less torque than those which are Zn plated. Also Cd plated electrical contacts retain a high surface conductivity longer than the Zn plated ones; Cd is not to be preferred to Ag plated contacts. The question of H_2-embrittlement is discussed and the advantage of Cd in a marine environment is indicated.—C.V.

Radiant firing lengthens life of galvanizing kettle J. Atkinson (*Products Fin.*, 1960, **25**, Nov., 56–58) This kettle has been in use for over eight years; previous to using radiant heat, the maximum kettle life was about four years. The conversion of the furnace to radiant gas burners is briefly described and the galvanizing process is outlined. It is found that, with this combustion system, bath temp. can be held consistently and considerably less dross is formed, so that Zn consumption is reduced.

Heating of galvanizing baths Tancred & Langley Ltd (*Wire Ind.*, 1960, **27**, Dec., 1201) A system, the 'Instantheat', is briefly described which differs from other systems in that the hot gases impinge on the bath wall normal to its surface, instead of being passed around the periphery parallel to its surface, all the hot gases being brought into intimate contact with the bath and avoiding hot spots at corners or other localities where in conventional systems a change in direction of the gases occurs. Various other advantages are claimed.

Effects of additions in zinc on its flowability during the galvanizing of steel I. B. Serebryakova, Z. P. Men'shikova, and N. S. Smirov (*Stal'*, 1961, (1), 92–94) Studies were made with pure zinc and alloys with small amounts of Fe, Pb, Sn, and Al. Maximum flowability was shown by pure zinc or zinc with $>2\%$Pb. The alloy with 9%Sn shows an anomaly for which an explanation is suggested.

Efficient monorail system absorbs finishing line J. K. Harlow (*Iron Age*, 1961, **187**, Jan. 12, 62–64) An automatic system for zinc-plating telephone equipment through ten stations and over about 3000 ft of total track, with a minimum of handling from start to finish, is described.—S.H.-S.

Advances in the electrolytic deposition of bright tin coatings S. C. Britton (*Metalloberfläche*, 1960, **14**, Sept., 277–281) Experiments carried out at the Tin Research Institute, Middlesex, are described, with reference to the use of a wood tar derivative as a brightening addition in stannous sulphate and other baths.

Tin mill products J. E. C. McKenzie (*BHP Rev.*, 1960, **37**, Oct., 5–8) Extensions to this plant will raise capacity to 118000 t/year and an electrolytic tinning line will be in production by 1962. In conjunction with this, a five-stand cold mill and a slitting line are being installed in connexion with the flat products division; this will facilitate large-scale production of cold rolled strip at this centre. A general description of the various units is provided.—C.V.

The problem of fracture of ultra-high-strength steel electroplated with cadmium P. N. Vlannes, S. W. Strauss, and B. F. Brown (*ONR-5*, **2**; *PB* 161471, 463–474) The authors have investigated a very large number of plating solutions, with a view to finding one that will cause a minimum of hydrogen embrittlement. The use of triethanolamine as a complexing agent was promising.

Hydrogen embrittlement of cadmium plated spring steel J. A. Gurklis, L. D. McGraw, and C. L. Faust (*Plating*, 1960, **47**, Oct., 1146–1154) Methods of pretreatment, plating, and finishing giving products free from embrittlement are given. The work was carried out at the Battelle Institute under Army Signal Corps contracts.

Development of a non-embrittling cadmium electroplating process. V. Use of pyridine as a complexing agent in cadmium plating solutions S. W. Strauss and P. N. Vlannes (*Plating*, 1960, **47**, Sept., 1037–1039) Plating characteristics of the Cd–pyridine bath, with and without additives, have been investigated. Best results (semi-bright) are attained with an aqueous solution containing M Cd and 30 volumes% pyridine; current efficiency approaches 100% and the throwing power approaches that of the CN-bath at small distance ratios of far-to-near cathode. At room temp. it was shown that continuous plating could be achieved for 24 h/day for at least 30 days, no attention was required beyond maintenance of constant volume of solution and renewal of the Cd anodes. Results of delayed fracture tests using plated cylindrical notched specimens of AISI 4340 steel heat-treated to $\sim$285000 psi UTS and subjected to an applied load 75% of the notch tensile strength of the unplated specimen, showed that this type of bath is non-embrittling.

Composite-bonded metals resist chemical and nuclear attack A. P. Krapp (*Iron Age*, 1960, **186**, Oct. 13, 90–91) A new line of lead-clad metallurgically bonded metals in course of production offering properties of an ideal chemical and nuclear shield is briefly described with their various characteristics and uses.

Properties of plasma-sprayed materials M. A. Levinstein, A. Eisenlohr, and B. E. Kramer (*Weld. J.*, 1961, **40**, Jan., 8s–13s) New arc-plasma equipment for the spraying of metallic and non-metallic materials is briefly described, spraying parameters being established based on density and microstructure and selected physical properties measured being density, thermal expansion, and hardness. Crystallographic studies were made to determine stability of materials, and deposited materials analysed for oxygen and nitrogen. Tensile heating of the metals was conducted at temp. including 4500°F for W and 3000°F for Mo.—S.H.-S.

Controlled deposition of protective calcite coatings in water mains R. F. McCauley (*J. Amer. Water Works Assoc.*, 1960, **52**, Nov., 1386–1396) A coating process is described in detail using polyphosphate and pH adjustments suited to the hardness of the water.

Picking a coating to resist water corrosion C. G. Munger (*Mat. Design Eng.*, 1961, **53**, Jan., 71–75) Six organic coatings, lead–zinc silicate, and concrete with their advantages and limitations are listed and discussed. The type of corrosion, the mechanism, and method of application are summarized.—C.V.

Integral chromate coating protects galvanized strip Weirton Steel Co. (*Steel*, 1960, **147**, Oct. 3, 74–75) Chemical reaction of dissolved chromium compounds with the zinc surface, producing a gel-like coating called Iridite 9P–3, resistant to corrosive materials and environments, is briefly discussed.—S.H.-S.

The development of the coating of steel with plastics. II F. Wiesner and M. Zezulova (*Hutn. Listy*, 1960, **15**, (12), 971–978) The paper, a continuation of a survey begun in *ibid.*, (9), 694–699) deals with the present state of development and application of plastic coated steel wires and tubes.—P.F.

Plastic-coated sheet, its properties and possible applications G. Frank (*Metalloberfläche*, 1960, **14**, Sept., 282–284) Methods of bonding plastic foils to steel and Al strip are outlined briefly, and applications discussed.

Hydrogen in steel and the enamelling process C. L. Bijl (*Metalen*, 1961, **16**, Jan. 16, 7–11; Jan. 31, 24–28) The H_2 content in steel is investigated from the viewpoint of its being the cause of fish-scale defects in enamel coatings. The behaviour in this respect of three kinds of steel (two oxidizable and one stainless) is dealt with and it seems that the fish-scale tests give helpful results provided other factors like thickness, stress, and adhesion are held constant. It is suggested that improvement in the enamelling is possible by reducing the H_2 content, the adoption of electric smelting and the employment of suitable surface active materials, particularly clay.—F.R.H.

Sprayed metal coatings J. T. Crennell (*Chem. Ind.*, 1961, Feb. 11, 162) A letter. The preference for an Fe-containing Zn as a protective coating for steel is discussed, specially for endurance or immersion in sea water. The bulk of galvanized steel is exposed to the atmosphere and the previous argument would suggest that an Fe-containing Zn corrosion rate is less than that of high purity Zn. There would appear to be no experimental evidence to support this view. Zn-pigmented paints are considered. In these both galvanic activity and self-corrosion are restricted by the paint medium, and laboratory tests in progress suggest that a Zn-rich paint, prepared with 'Fe-suppressed' Zn powder gives a longer endurance than a similar paint of commercial Zn-powder. The test is that of full immersion in sea-water of painted steel panels with a scratch through the paint on one face.—C.V.

Further developments in metal spraying techniques H. Reininger (*Metalloberfläche*, 1961, **15**, Feb., 52–57) Means available for metal spraying are discussed and necessary pre-treatment as well as after-treatment described. Structures, properties, and testing of the sprayed layers are dealt with, followed by examples of their uses for corrosion protection, repair and for finishing.—R.P.

Sprayed metal coatings in the gas industry R. E. Mansford (*Chem. Ind.*, 1961, Feb. 11, 150–160) A general review. The treatment of the Spanish National Steelworks gas holders by Al spraying is specially mentioned as well as the Abbey Steel Works in South Wales where 99·5%Al was used to a thickness of 0·004–0·005in. The coating was painted but no other treatment was given, and this has lasted four years, while two smaller gas holders which were only painted have corroded to a considerable extent. Heat-treatment, alloy processes, aluminized-Cu, and the use of high Ni alloys are also dealt with. It is also pointed out that any yielding or creep in the base material will disrupt the coating and the use of a combined organic coating with a metal coating is reported but this is still in an early stage of development.

Repair of worn and broken parts. IV S. D. Scorer (*Steam. Eng.*, 1961, **30**, Jan., 128–130) The fourth of a series of articles dealing with practical methods of motoring worn or broken parts of engineering plant and particularly boiler plant, discusses metal spraying, hard-facing, and electro-chemical deposition. The Deloro Stellite hard-facing process and the FESCOL electro-chemical deposition process are briefly described.—S.H.-S.

Protecting iron by oxidation D. J. Fishlock (*Corros. Prev.*, 1960, **7**; *Corros. Eng.*, **2**, Oct., i–iii) The properties of protective oxide coatings produced by various methods are discussed.

Protective layers on steel surfaces obtained by means of alkali phosphates. I C. Braniste, D. Peretz, and S. Serban (*Bul. Inst. Jasi*, 1960, **6**, (1–2), 133–138) The factors influencing phosphatization of steel surfaces at room temp. were studied in alkali phosphate solutions Optimal results were obtained with an alkali phosphate concentration 50–130 g/l, pH 3, and the ratio of oxidizing agent/phosphate 1:10–1:18, when the protective layer obtained was uniform and of good adherence and appearance, resisting the drop test for 4–5 min.

Coated steel John Summers and Sons Ltd (*Engineering*, 1961, **191**, Feb. 17, 272) 'Stelvetite' (steel coated with vinyl plastic) products as applied to light furniture in the home is discussed and illustrations are provided (trolley, record-player table, three-shelf bookcase, coffee tables, etc.).—C.V.

Metals plus plastics delay fatigue and corrosion Boeing Airplane Co. (*Iron Age*, 1960, **186**, Nov. 10, 178–179) The proper combination of metals, plastics, and adhesives for the light-weight strength of helicopter blades designed to pass an endurance test of 6000 h of actual service is discussed and their production described.—S.H.-S.

Vitreous enamelling J. K. Whitaker (*Prod. Fin.*, 1960, **13**, Sept., 81–87) The practice followed by one of the largest plants in the UK is described. The preparation of the enamel, the sheet metal, the application of the enamel and development work are briefly summarized Work with sheet and cast iron is covered together with spraying, mottling, and lustre.

Can enamels and ceramic coats curb corrosive attack? G. L. Geltmann (*Iron Age*, 1960, **186**, Nov. 17, 148–150) A review of the available types on the market and their effectiveness under present conditions, with indication of the need for new and better coatings to meet the requirements of new fuels, space flight, and new industrial uses.—S.H.-S.

The appearance of defects in cast iron enamels. I H. Koerver and O. Hildebrand (*Giessereitech.*, 1961, **7**, March, 76–80) The requirements for the chemical composition, structure, and surface characteristics of cast iron for enamel purposes are reviewed, followed by the operations of the enamelling process and the defects appearing in the enamel. The effects of low-C content, C and Si content, Mn and P content, and the S content of defects occurring in the course of classifications and melting, as well as those of the moulding sand and mould preparation, are studied and evaluated.—M.L.

Abrasion resistance of vitreous enamels Institute of Vitreous Enamellers (*Found. Trade J.*, 1961, **110**, March 2, 269–273) Various methods of testing for abrasion resistance are examined, special attention being paid to reproducibility; samples of sands are also examined, Redhill sand being specified as the standard. The test apparatus adopted is briefly described. A discussion, introducing various viewpoints, is included.—C.V.

The effect of detergents on vitreous enamel Institute of Vitreous Enamellers (*Met. Fin. J.*, 1960, **6**, March, 87–94, 102) The pH of nine proprietary detergents is listed and these with Na_2CO_3, Na_4PO_7, Na_2SO_4, Na-dodecylbenzenesulphonate and various electrolytes are examined using eight types of sheet-iron enamel and four cast iron enamels. It is shown that enamels vary in their resistance to detergents while vary in their corrosiveness. The BS.1344 test for alkali resistance is not suitable for the determination of resistance to detergents. Corrosiveness does not, in general depend on pH. A semi-opaque AR titania enamel with a specially formulated frit gave the best resistance. It is shown that the finer the grinding of the enamel, the better the resistance, while opacifiers possess a slightly adverse effect. Coloured oxides can also act adversely. A Zr-opacified bath enamel possessed better resistance than an Sb-opacified dry process enamel.—C.V.

Machine steps up paint mileage E. A. Zahn (*Iron Age*, 1961, **187**, March 16, 116–117) An oscillating-reciprocator, which sprays paint with flow-coat action by dual motion, and is of French origin, is briefly described, with potential plant uses.—S.H.-S.

Roughness of steels and thickness of multiple-coated anti-rust paints (*Peint. Pig. Ver.*, 1961, **37**, March, 127–129) An editorial, urging the preparation of steel surfaces by pelletizing or similar action in the interests of paint economy.—S.H.-S.

Industrial metal finishing techniques. II J. J. Stordy and W. G. J. Appleton (*Product. Fin.*, 1960, **13**, Sept., 69–75) Conventional paint application, electrostatic spraying, and the use of 'airless spraying' are compared and discussed. Attention is drawn to 'curtain coating', a new development which at present can only be applied to flat shapes. The workpiece is passed along a conveyor, paint being fed to the surface in passing by means of a slot in the paint container which is under slight pressure; this gives a cushion effect and ensures that the volume applied is constant over the full width; film thickness depends on the speed of passage and width of slot employed. This form of application is at the moment chiefly used with wood as with metals a very high speed is required and this entails a drying problem.—C.V.

King overhead conveyor system for French factory (*Brit. Eng. Transport*, 1961, **43**, March, 262–264) A complex overhead conveyor system for the paint shop of the Poissy plant of Simca cars is described.—S.H.-S.

CLAD SHEET AND HARD FACING

On joining stainless and plain carbon steels in the production of clad sheet M. Žídek (*Hutn. Listy*, 1961, **16**, (1), 19–28) [In Czech] A metallurgical study was made of the effect of the main variables, e.g. heating times and temp., cooling rates, carbon diffusion, etc., on the formation of the joints in thick clad steel sheet rolled from compound ingots.—P.F.

Hard chrome in the manufacture of armaments L. L. Morales (*Met. Elect.*, 1961, **25**, Feb., 94–100) A brief study of the use of chrome in the rifled inner tubes of gun barrels varying in calibre from 1½ to 6in and barrel length from roughly 10 ft to 23 ft, with a comparison of the hardness of electrolytic chrome and gun steel and directions for the distribution of chrome in the bores, with attention to the difficulty of even chroming within nominal tolerances, and the qualities essential in the preparation of an anode. The actual operation is described and discussed, with graphs indicating the speed of deposit if electrolytic chrome and the relation between temp. and densities of currents.—S.H.-S.

A new Stellite hard-facing process Delloro Stellite Ltd (*Machinery*, 1961, **98**, March 8, 538–539) A new process for the deposition of Stellite heat- abrasion- and corrosion-resistant hard-facing powders, known as powder welding, carried out by a Schori specially adapted powder-spraying pistol, to which powder is fed from a hopper by a stream of argon, with oxygen and acetylene providing the heating flame, is described. The rate of deposition is claimed as double that of normal gas welding and four times that of arc welding.—S.H.-S.

POWDER METALLURGY

Powder metallurgy in practice (*Machinery's Yellow Back Series No.*23, Machinery Publishing Co., 1959, pp.70) A succinct review. A short bibliography of 23 references is included.

Sintering helps the designer (*Eng. Mat. Design*, 1961, **4**, Jan., 18–24) The metal sintering process, design criteria, and some recent developments are reviewed.

Reduction of powdered iron oxides: a vertical flow reactor W. A. Lloyd and N. R. Amundson (*Ind. Eng. Chem.*, 1961, **53**, Jan., 19–22) A study on reactions of H_2 with pigment grade Fe_2O_3 and taconite by means of a vertical flow reactor on extremely small particles, about 0·3 μ in dia.—S.H.-S.

Reduction of powdered iron oxide: a tubular reactor I. G. Dalla Lana and N. R. Amundson (*Ind. Eng. Chem.*, 1961, **53**, Jan., 22–26) Following on the previous study with a small reactor, the use of coarser particles in a 16 ft reactor is studied. Using a prepared ore, about 95% reduction was rapidly attained. The operation and results with the proposed mechanism are described.—S.H.-S.

On the reactivity of iron powders produced by the reduction of ferric oxides: influence of the method of preparing the oxide J. Hui (*Compt. Rend.*, 1961, **252**, Feb. 27, 1325–1327) A study of the atmospheric reoxidation and the reaction in water of iron powders prepared by thermic reduction of different ferric oxides. Confirmation of the great reactivity of irons produced under low hydrogen pressure is presented, with evidence of the considerable influence upon this reactivity of the anion of the iron salt from which the oxides were prepared.—S.H.-S.

Strip steel from iron ore Republic Steel Corp. (*Iron Coal Trades Rev.*, 1961, **182**, March 3, 471) The steel strip rolling process uses iron powder and by-passes the normal production

operations such as coke ovens, blast-furnaces, open-hearths, and blooming mills and therefore has the potential of reducing capital equipment and production costs very considerably while at the same time producing a steel of quality equal to that produced by conventional methods. Iron ore is highly purified and reduced to metallic iron powder, funnelled between four rolls into a semi-solid strip which passes through a furnace at 1200° in a reducing atmosphere. It is then passed through a series of hot-strip rolling stands which reduces the thickness to the desired gauge and to full density in the form of hot-rolled steel in coils. The normal processes follow, pickling, cold rolling, and annealing, before recoiling or cutting into sheets. More than 1800 lb of steel has been produced by this method and a model of the unit is shown.—C.V.

For stronger, tougher metal-powder parts F. Giordano (*Prod. Eng.*, 1961, **32,** March, 78–79) It is pointed out that although the use of high densities will cost more, higher strengths and ductility, better dimensional accuracy, finer surface finish, increased resistance to wear, and less surface porosity is attained as compared with conventional practice. Such parts are made by pressing the powder at 50–60 t/in^2, sintering, and then further increasing the density by a second pressing. Graphite is not used since C forms an alloy with Fe during the sintering and this makes pressing to high density difficult. Examples are given and the economics are discussed.—C.V.

Influence of oxygen content on the characteristics of iron powders and sintered products A. Bia (*Met. Ital.*, 1960, **52,** Dec., 953–957) [In Italian] Research has shown that the degree of oxidation of dusts has a big influence on the compressibility, i.e. on the density attainable at constant pressure. As a proportional relationship exists between density and tensile strength—by decreasing the compressibility the tensile strength of sintered products also decreases. Mechanism is discussed.

On the lubricants mixed into iron powder T. Tabata (*J. Japan Soc. Powder Met.*, 1959, **6,** Aug., 149–154) In this paper the lubricating abilities of several organic lubricants used in the powder metallurgy industry are investigated. On five kinds of lubricant stearic acid and its Zn, Al, Pb, and Ca salts mixing with Höganäs sponge-iron powder, the following properties are studied, zinc stearate is standard: (1) dispersibility for mixing into metal powder, (2) effects on the physical characteristics of metal powder, (3) lubricating abilities for powder compacting and ejecting.—R.F.S.C.

New family of metal graphites handles many bearing jobs M. Humonik jun., D. W. Hall, and R. L. Van Alsten (*Iron Age*, 1960, **186,** Nov. 10, 171–173) A new series of metal-bonded graphites, the result of a process preventing sweating during sintering of powder compacts, combine anti-friction properties and strength, and can be used in both dry and lubricated bearings. Results are presented.

FERRITES, CERMETS AND CARBIDES

Fundamental studies on cermet. II. Experimental studies of surface tension of substitutional binary alloys. III. Experimental studies of the surface tension of (Fe, Co, Ni)–C alloys K. Monma and H. Suto (*Nippon Kinzoku*, 1960, **24,** (3), 163–167; 167–170) [In Japanese] II. Data are given for Cu-, Fe-, Ni-, and Co-base alloys containing Mo, W, Si, and Cr. In binary alloys, surface tension changes in coincidence with the liquidus line. At the m.p., the dissociation of intermetallic compounds is imperfect. The surface tension of alloys containing impure Cr decreases with Cr concn. III. The effect of C addition on surface tension is slight with pure Fe, Co, and Ni (Fe, Co, Ni)–C alloys and (Fe, Co, Ni)–(Mo_2C, WC) alloys (13 refs).—K.E.J.

New heat-treatable carbides offer job versatility J. L. Ellis (*Iron Age*, 1961, **187,** March 2, 92–94) A new steel-bonded carbide, Ferro-Tic 'C', consisting of 45%TiC by volume, bonded with chrom-moly alloy steel, and claiming a steel's heat-treating and forming traits, with the wear resistance of a carbide, is presented.

Manganese–zinc ferrites B. Pataki (*Magyar Hiradástechnika*, 1960, **11,** (3), 104–107; from *Hungarian Technical Abstracts*, 1961, **13,** (1), 15) The magnetic properties of Mn–Zn ferrites are more advantageous for use with low frequencies than those of Ni–Zn ferrites. The properties of Mn–Zn ferrites are decisively affected by the quality, purity, and grain size of the basic materials—by the composition of the mixture, temp., and atmosphere of the final sintering. Accuracy of composition must be maintained and oxidation of the Mn during cooling must be prevented. Data of the type of ferrite for use in telecommunication engineering are published.—R.S.F.C.

PROPERTIES AND TESTS

Mechanical properties and chemical resistance of high-strength corrosion and acid resistant steels H. Zitter (*Draht*, 1960, **11,** Aug., 438–441) The properties of a number of ferritic, austenitic, and semi-austenitic steels are reviewed.

A synthesis of the results of Belgian investigations on the correlation between section size and physical properties of grey cast irons A. De Sy and J. van Eeghem (*Inst. Hierro Acero*, 1960, **8,** Oct.–Dec., 847–860) [In Spanish] A résumé of the results of a large-scale investigation of the properties of grey cast iron as a function of section size is given (13 refs).

New furnace operates at 3100° C (*Eng. Mat. Des.*, 1961, **4,** Feb., 99) An electrically-heated resistance furnace with a graphite resistor, developed by General Electric Co. Ltd, and the Atomic Energy Authority, Harwell, to operate at up to 3100°C, is described with operational data.—S.H.-S.

Anisotropy and mechanical properties of grey cast iron J. S. Abcouwer (*IGK Kongress Vorträge*, 27th International Foundry Congress, Zürich, 1960, 263–275) [In German] By means of an indirect proof, an equation is derived describing heat flow. A formula for the total cooling period of a simple casting is deduced. Undercooling of the austenite–pearlite reaction with respect to R (the fraction volume divided by the surface area of the casting) is discussed, and the relationship between Brinell hardness and undercooling examined. It is shown that three equations are sufficient to describe the mechanical properties of simple compact, unalloyed grey castings (46 refs).

Laboratory-scale casting furnace for high-melting-point metals P. G. Clites and E. D. Calvert (*US Bur. Mines, RI* 5726, 1961, pp.13) A laboratory size, consumable-electrode, skull-casting furnace equipped with a water-cooled copper ladle was developed by the Federal Bureau of Mines. Castings of various reactive and refractory metals have been made from up to 20in^3 of molten metal.

Concerning the link between the strength of materials and of the manufactured part under the action of static, cyclic, and impact loads N. B. Baranova (*Ustalost', Metallov*, Moscow, 1960, 148–157) The strength properties of materials, particularly for links of the DT–54 caterpillar tractor, were investigated in view of a suggestion to replace high-ductile steel G–13L with cast steel 35KhG2T. Mechanical properties are listed (10 refs).—A.I.P.

New instrument grades polished metal surfaces W. H. Tingle and F. R. Potter (*Prod. Eng.*, 1961, **32,** March 27, 52–53) This simple optical system uses a photocell to scan light reflected from the sample; it gives readings that are both more rapid and accurate than those obtained by subjective visual methods. The instrument and findings are described, discussed, and illustrated.—C.V.

Measurement of the surface roughness of cast iron A. Kolorz and K. Löhberg (*Giesserei*, 1960, **47,** Sept. 8, 472–475) Step-wedge specimens were cleaned electrolytically, as mechanical cleaning gave unsatisfactory results, and roughness measured by a scanning method.

The phenomenon of seizure and its investigation A. P. Semenov (*Wear*, 1961, **4,** Jan.–Feb., 1–9) The phenomenon is divided into two parts: sintering and seizure, sintering having the nature of a diffusion process while seizure is a result of mutual plastic deformation of metals, but without diffusion. Deformation of sheet specimens by plain narrow punches and symmetrically-inclined punches made it possible to investigate the influence of different factors on seizure. In the discussion of results it is assumed that for seizure not only must there be intimate contact of clean surfaces, but that an energy barrier must be overcome. Other hypotheses of seizure are considered and the influence of chemical composition on seizure is shown to be considerable in the case of copper alloys.—S.H.-S.

Determination of surface state E. Bodart (*Rev. M. Tijd.*, 1960, **6,** (4), 211–222) Critical definitions of macro- and micro-geometrical surface irregularities are given and the effect of surface state on fatigue behaviour is discussed. Various laboratory and works methods for determining surface irregularities are compared for relating surface state with fatigue behaviour.—R.P.

The applications of internal friction. Method to the studies on iron and steel. II. On the recovery of internal friction of low carbon steels after cold-work K. Aoki, S. Sekino, and T. Fujishima (*Nippon Kinzoku*, 1960, **24,** (4), 246–249) [In Japanese] Recovery results for commercial pure iron and Al-killed deep-drawing sheet are explicable by the Granato-Lücke theory in relation to diffusion of C and N atoms and dislocations.—K.E.J.

Investigation by internal friction and tensile tests of the precipitation of nitrogen in pure iron–nitrogen alloys. Application to the ageing of extra-mild steels G. Collette, C. Roederer and C. Crussard (*Rev. Mét. Mém. Sci.*, 1961, **58,** Jan., 61–72) Parallel measurements of internal friction, using a hysteresis-measuring apparatus, and tensile tests on micro-specimens, both on the pure alloys and on commercial low-N_2 extra mild steels, indicated that N_2, at any rate in low concentrations, is not significantly responsible for the ageing occurring after quenching these steels (13 refs).

Internal friction in martensite and tempered martensite T. Ichiyama, M. Kawasaki, and K. Takashina (*Nippon Kinzoku*, 1960, **24,** July, 456–461) [In Japanese] Steels with 0·68, 0·85, and 1·14%C were tested with a torsion pendulum. The carbon peak relaxation was observed in the 0·68%C specimen often quenching but not in the others supporting the idea that these have a superlattice structure. In tempered martensite a peak was observed at about 225°C with a continuous increase in internal friction with increase of temp. from ~280°.

Static and dynamic elastic constants L. Gold (*Brit. J. Appl. Phys.*, 1960, **11,** Nov., 522–523) In a paper 'Microcracks and the static and dynamic constants of annealed and heavily cold-worked metals', Bristow (*ibid.*, Feb.) drew attention to the difference between the static and dynamic bulk modulus and Poisson's ratio for Al, Cu, and Ni determined from measured values for Young's modulus and the shear modulus. A difference was also observed in the Poisson ratios measured directly. Similar differences have been noted with ice (L. W. Gold, *Can. J. Phys.*, 1959, **36,** 1265). This problem is regarded as being solved by an equation which indicates that two processes are involved In one, Poisson's ratio of ~0·30 is attributed to the elastic deformation of the grains while in the other (or subsequent processes) an effective ratio of 0·88 is recorded which would appear to result in the relaxation of stresses along preferred planes; this would refer particularly to those associated with the constraints imposed by the grain boundaries. In ice, this higher ratio value would occur with multigraining because of the symmetry involved. Movement caused by relaxation of stresses associated with grain boundaries would occur primarily in the direction normal to the long axis of the columnar grains. The validity of applying this argument to metals is considered, especially as ice is columnar in structure while metals are normally granular and, even if the mechanisms involved are different, the conclusion still remains that the usual relationships between elastic moduli may not be valid under all conditions of stressing. This is particularly applicable to a material where two deforming processes appear to be active.—C.V.

Elasticity and plasticity of an austenitic chromium–nickel steel K. Salmutter and F. Stangler (*Z. Metallk.*, 1960, **51**, Sept., 544–548) Experiments were made on the elastic and plastic deformation of single crystals of a 12%Cr 12%Ni steel. The elastic parameters were determined from the moduli of elasticity and torsional shear. It was found that the elastic anisotropy of γ-iron is much greater than that of α-iron. The critical shear stress for octahedral translation is 5·5 kp/mm^2.

Energy absorption, unit force and spring material K. Walz (*Draht*, 1960, **11**, Nov., 718–721) The selection of materials for springs is discussed mathematically with particular reference to the helical spring. A formula is derived which facilitates the choice of the type of spring best suited for the purpose and of the best material. Heat-treatment of spring steels is also dealt with.

Factors affecting the ductility of iron–chromium–aluminium alloy sheet R. W. Endebrock, E. L. Foster, jun. and R. F. Dickerson (*BMI*–1450, 1960, July, pp.24; from *US Res. Rep.*, 1960, **34**, Nov. 18, 660) [no abstract].—C.F.C.

Strain-hardening and crystalline fracture of polycrystalline iron A. W. Sleeswyk (*Acta Met.*, 1961, **9**, Jan., 32–39) The influence of pre-straining tensile specimens of Armco iron at room temp. on their yield and fracture stresses at lower temp. has been investigated, and the influence of strain rate on the fracture stress at liquid-nitrogen temp. has also been studied. It is shown that the plastic deformation obeys an equation of state: $\sigma=\sigma_1\ (\epsilon)+\sigma_2\ (\epsilon_1\ \mathrm{T})$ and the observed fracture stresses are explained by assuming that the crystal grains and the microcracks they contain are deformed in conformity with the bulk of the material. At temp. above 85°K only during the propagation of Lüders bands are microcracks formed. Below this temp. microcracks may also develop in later stages of plastic deformation: this is presumably due to twinning. In the latter case a size effect must be expected.—S.H.-S.

Plastic yielding in anelasticity M. Reiner (*J. Mech. Phys. Solids*, 1960, **8**, Aug., 255–261) Use of a criterion that the part of the stress-work conserved reaches a definite maximum at yielding is extended to creep and stress/strain dependence at constant strain rate.

Travelling cracks in elastic materials under longitudinal shear F. A. McClintock and S. P. Sukhatme (*J. Mech. Phys. Solids*, 1960, **8**, Aug., 187–193).

Transient increase of internal friction in the course of isothermal precipitation of carbon in non-iron–carbon alloy G. Collette (*Compt. Rend.*, 1960, **251**, Dec. 19, 2930–2932) A study of the evolution, as a function of time, of internal friction in an iron–carbon alloy, in the course of the isothermal precipitation of carbon, after being made soluble in the α-phase followed by water quenching has given evidence of a transient increase of internal friction.—S.H.-S.

Void formation in ductile fracture of a cobalt iron alloy C. W. Chen (*Acta Met.*, 1961, **9**, Jan., 68–71) A letter. The formation of voids in ductile fracture at room temp. is discussed, and it is stated that voids have been produced in three different microstructures. Various aspects of the subject are discussed.—S.H.-S.

Decomposition of dislocations in iron and cubic body-centred metals C. Crussard (*Compt. Rend.*, 1961, **252**, Jan. 9, 273–275) The existence of decomposed dislocations and faults of piling, well-known in cubic face-centred metals is not established for body-centred cubic metals. The present note studies the crystallographic conditions that these defects must fulfil, the important role that the Suzuki effect must play (segregation in the defect of atoms in insertion) and shows that a number of the mechanical properties of iron can thus be explained.—S.H.-S.

Arrangement of dislocations in iron W. Carrington, K. F. Hale, and D. McLean (*Proc. Roy. Soc.*, 1960, **259**, Dec. 6, 203–227).

Some kinetic considerations of the Griffith criterion for fracture. I. Equations of motion at constant force J. P. Berry (*J. Mech. Phys. Solids*, 1960, **8**, Aug., 193–206).

Some kinetic considerations of the Griffith criterion for fracture. II. Equations of motion at constant deformation J. P. Berry (*J. Mech. Phys. Solids*, 1960, **8**, Aug., 207–216).

Hartree-Fock atomic scattering factors for the neutral atom iron transition series A. J. Freeman and R. E. Watson (*Acta Cryst.*, 1961, **14**, March 10, 231–234).

An apparatus for the determination of thermodynamic constants of solids by the method of isotope exchange B. Žitňanský and I. Šebastian (*Hutn. Listy*, 1960, **15**, (12), 951–955) A special Knudsen cell developed by the authors is described. This was used in measurements of the thermodynamic stability of several Cr–Ni steels. Results confirmed that Mo additions, by increasing the observed heats of sublimation of the constituent elements, increase the thermodynamic stability of the steels. Pile irradiated specimens were used.

The critical phenomena between solids and fluids K. Furukawa (*Nature*, 1960, **188**, Nov. 12, 569–570) A letter. Critical point data for iron are included.

Effects of molybdenum, tungsten and copper on the solubility of graphite in liquid iron and the method of calculation of the activity of carbon in a multicomponent solution T. Mori, K. Aketa, H. Ono, and H. Sugita (*Tetsu to Hagane*, 1960, **46**, Oct., 1429–1437) Interaction parameters are evaluated and an approximate equation for the activity coeff. of C is given. The validity of the equation is discussed, and interaction parameters for infinitely dilute and saturated solutions are compared

An electrical analogue solution for the stresses near a crack or hole in a flat plate S. C. Redshaw and K. R. Rushton (*J. Mech. Phys. Solids*, 1960, **8**, Aug., 173–186).

On the new tensile testing machine H. Yoshida (*J. Japan Soc. Test. Mat.*, 1960, **9**, May, 367–371; from *Japan Sci. Rev. Mech. Elect. Eng.*, 1960, **7**, Aug., 172) [no abstract].

A correction formula for local contraction of tensile specimen with rectangular cross section K. Takase (*Proc. 3rd Japan Congr. Test. Mat.*, 1960, 107–110, [In English]; from *Japan Sci. Rev. Mech. Elect. Eng.*, 1960, **7**, Aug., 172) [No abstract].

Size effects on the tensile properties of large bars of AISI 4340 steel W. J. Fedyna and W. Golding (*ONR*–5, **2**; *PB* 161471, 576–595) The authors tested the size effect and the effects of interrupted quenching and of isothermally transformed specimens related to % martensite.

Fracture of the notched bar tension specimen K. Terazawa, M. Otani, T. Yoshida, and K. Terai (*Osaka Univ. Fac. Eng. Techn. Rep.*, 1960, **10**, Oct., 763–778) The notch shapes producing cracks at the centre were investigated and the rim effect was shown to be present only where this was the case. The centre crack was fibrous in type and the contour crack a shear type. Microdefects appeared to have considerable influence on crack initiation.—C.F.C.

Evaluation of stress-strain recorders R. R. Bouche and D. R. Tate (*Wire Wire Prod.*, 1960, **35**, May, 615–616, 653) An account of NBS work. Calibration methods and results are given.

Tensile properties of types 304 and 347 austenitic stainless steel in the temperature range from 75°F to 800°F W. H. Pryle and R. H. Hooke (*NP*–8720, 1956, Sept.-Oct., pp.60; from *Nucl. Sci. Abs.*, 1960, **14**, Nov. 30, 3015) Tests were conducted to determine the minimum yield strength, 0·2% offset, of annealed 304 and 347 stainless steels as a function of temp. in the range 75 to 800°F. Considerable variations of yield strength were found and such variations appear to be directly related to the as-annealed hardness. Yield strength increases as hardness increases in a linear fashion for the hardness range examined. As-annealed hardness is the predominant yield strength controlling factor while carbon and silicon content are secondary controlling factors. Test data for use as a basis for other investigations and for background information are included.—C.F.C.

The effects of inelastic action on the resistance to various types of loads of ductile members made from various classes of metals. Part XII. Eccentrically-loaded tension members and columns made of 17–7 PH stainless steel and Ti 155A titanium alloy and tested at various temperatures O. M. Sidebottom and S. Dharmarajan (*Rept. on Materials Analysis and Evaluation Techniques, WADC Tech. Rep.*, 56–330 Pt XII; *PB* 161836; from *US Res. Rep.* 1960, **34**, Oct. 14, 480) Tests on the steel at 1000°F showed time dependence. The arc hyperbolic sine theory gave good agreement with experimental values.

The sharp edge notch tensile strength of several high-strength steel sheet alloys G. B. Espey, M. H. Jones, and W. F. Brown, jun. (*Proc. ASTM*, 1959, **59**, 837–871) This test has been used in order to provide design data for the sensitivity of alloys to low stresses in the presence of high stress concentration. The way in which the data can be used is shown.

Effect of cold rolling and stress relief on the sharp edge notch tensile characteristics of austenitic stainless steel sheet alloys G. B. Espey, A. J. Repko, and W. F. Brown, jun. (*Proc. ASTM*, 1959, **59**, 816–832) Characteristics were determined at room temp. and −320°C, for AISI 301 and AISI 304L cold-rolled sheet.

Tension, compression, and fatigue properties of several steels for aircraft bearing applications G. Sachs, R. Sell, and W. F. Brown, jun. (*Proc. ASTM*, 1959, **59**, 635–657) Various heats of SAE 52100 steel and vacuum-melted tool steels were tested. It appears that there may be some correlation between the rotating beam fatigue data for SAE 52100 and the median fatigue life of full-scale bearings made from the same heats.

Measurement of the tensile strength of brittle materials A. Ormerod (*Brit. J. App. Phys.*, 1961, **12**, Jan., 29–30) A statement that the tensile strength of brittle material (calculated from the breaking load applied in a bend test) may be more than double that found from a tensile test is criticized. It is pointed out that this discrepancy arises from the fact that the conventional formula is inapplicable if the material does not adhere closely to Hooke's law. The stress–strain curve for cast iron is discussed and the distribution of stress prior to fracture is examined, it being shown that if the precise shape of the stress–strain curve is known, the position of the neutral axis can be found by balancing the total tensile and compressive forces, and the bending resistance of the section can be found by integrating the moments of these forces. This is examined in further detail and the effect of surface finish is also considered.—C.V.

Experimental determination of energy release rate for notch tension J. D. Lubahn (*Yukinoir Takahashi Mag. Soc. Naval Arch. Japan*, 1960, June, 244–251; from *Japan Sci. Rev. Mech. Elect. Eng.*, 1960, **7**, Aug., 171) [no abstract].

Experimental determination of energy release rate for notch bending and notch tension J. D. Lubahn (*Proc. ASTM*, 1959, 885–913) Values of energy release rate were determined experimentally, as a function of notch depth, for notch bending and notch tension, and by means of fracture tests the critical energy release rate was determined for two steels. The results were compared with predictions based on the literature, and in particular with those derived from the Griffith-Irwin concept of a critical energy release rate.

Selected short-time tensile and creep data obtained under conditions of rapid heating D. P. Moon and W. F. Simmons (*PB* 151088, 1960, June 17, pp.88; from *US Res. Rep.*, 1960, **34**, Nov. 18, 622) Of the 28 alloys examined, two were alloy steels, three tool steels, and six were Cr–Ni–Fe alloys (121 refs).

A reversed-bend test for ductile-to-brittle transition J. H. Ludley and D. C. Drucker (*Weld. J.*, 1960, **39**, Dec., 543s–546s) A test is proposed based on the use of a sharply bent beam, to explore the effect of material and environment on the borderline between ductile and brittle behaviour in structural steel. Results, which are claimed to provide a reproducible laboratory test for preliminary study of such factors as ageing, amount of pre-compression, temp. of testing, machined *v.* as-rolled surface, etc., are presented, results also being given for project E-steel, A-7, and T-1, all of which show brittle behaviour in tension following large pre-compression and which are all adversely affected by ageing.

Correlation of bendability of materials with their tensile properties J. Datsko and C. T. Yang (*Trans. ASME J. Eng. Indust.*, 1960, **82**, Nov., 309–314) A simple equation is presented that correlates the minimum bend radius with the percentage reduction of area of the material. Theoretical and experimental data are compared and good agreement is obtained. Thus it is possible to predict the minimum bend radius for a specific material provided the percentage reduction in area is known; this is obtained by a standard tensile test. This relationship is equally applicable to metals and to non-metals. In discussion it is pointed out that with strain-rate sensitive materials, the strain-rate effect should be incorporated in the bendability data and it is noted that this will be included in a future study of this problem.

Behaviour of ductile cast iron under compressive stress P. K. Trojan, R. A. Flinn, and D. J. Reese (*Proc. ASTM*, 1959, **59**, 922–929) Austenitized and quenched blocks ½–2in thick, tempered 1 h at 1300, 1150, 925 and 300°F were sampled, machining specimens being prepared and compression strength for 0·1% offset ranging from 66000 psi (215 Brinell) to 215000 psi (585 Brinell). Details are given.

Material characteristics of Cons-el Arc melted bearing steel. (Properties of Cons-el Arc melted bearing steel. I) Z. Takao, M. Nishihara, and Y. Yagi (*Tetsu-to-Hagane*, 1960, **46**, Nov., 1543–1549) Vacuum melted steel (by the process named) was improved in macrostructure compressive strength and amounts of surface defects.

Research and development on the effects of high pressure and temperature on various elements and binary alloys J. S. Harvey and L. Kaufman (*PB* 161920, 1960, April, pp.99; *WADC Technical Rep.* 59–655; from *US Res. Rep.*, 1960, **34**, Nov. 18, 625) Apparatus working up to 100000 atm. and >1500°C is described. Effects on transformations in Fe–Ni were examined, as well as studies of non-ferrous alloys.—C.F.C.

Impact properties of induction hardened steels. (Charpy impact values and Matsumura's repeated impact bending test) M. Miyairi and T. Matsumoto (*Railw. Tech. Res. Rep.*, 1960, (129), June, pp.53; from *Japan Sci. Rev. Mech., Elect. Eng.*, 1960, **7**, Nov., 428) [No abstract].

Notch sensitivity in steel E. Agerman (*Acta Polytech. Scand.*, 1960, (Me 8), pp.42; *ASEA Res.*, 1960, (4), 5–46) Notch-effect formulae are compared and evaluated. A method of calculation is advanced in which the safety factor is associated with the probability of fracture.

On the transition temperature of strain-aged mild steels. (Studies of load-time relations by Charpy Impact tests. II) S. Sakui, T. Nakamura, and M. Ohmori (*Tetsu to Hagane*, 1960, **46**, Nov., 1538–1543) Killed steel with 0·17%C was tested on a miniature Charpy machine with piezo-electric crystal/oscillographic recording. Strain ageing for 3–100 days after 3 and 10% stretching did not change the transition temp. (25°) except with 60 min at 200° and 120 min at 200° for the 3 and 10% strained specimens respectively, when the temp. rose to 40°. Other findings are noted.

Overrating the notch-impact toughness in the appraisal of steel quality S. Kronmarck (*Technik*, 1960, **15**, Nov., 751–756) The author warns against overrating the notch-impact test in the appraisal of the steel quality for use in static structures such as buildings, bridges and so on, as overrating puts too great a claim on the producer and reduces output, while on the other hand no advantage is given by too strict requirements. The author quotes a number of cases from the literature and reports his own tests in which the notch-impact strength was no indication of the brittle-fracture tendency of a steel. He contests the usefulness of the dynamic test as a mean of appraisal of steel that is ultimately used in static structural work (25 refs).—T.G.

Fracture toughness of materials for aircraft and missiles H. L. Smith, J. A. Kies, and G. R. Irwin (*ONR*–5, **2**; *PB* 161471, 475–492) The use of a parameter called the critical toughness value, and the way it can be determined, are discussed. This parameter is useful for calculating maximum allowable stresses on very high tensile steels stressed to near the yield point. The parameter depends upon such things as strictness of inspection.

Explosion-bulge tests of armor weldments S. M. Silverstein, R. P. Sopher, and P. J. Rieppel (*Weld. J.*, 1960, **39**, July, 309s–314s) By comparison with the H-plate test, the explosion bulge test was investigated, to determine whether it was useful for evaluation of toughness performance of welds in Army Ordnance high-strength steel. It is concluded that, if the results are very carefully interpreted, the test is useful.

1959 References on fatigue ASTM Committee E-9 (*ASTM Publication, STP* 9–K, pp.88, 1960).

London Transport's axle fatigue tester (*Metalw. Prod.*, 1961, **105**, Jan. 4, 59–60; *Rail Gaz.*, 1960, **113**, Dec. 16, 714) This has been specially designed to determine the strength of specimens of axle steel when subjected to a rotating bending stress. The machine is of the resonant type with mechanical drive through a slipping clutch for starting and stopping; the specimens are 5 ft long by 5½in dia. with enlarged end. Of the two specimens tested one failed at 2910000 cycles at 16 t/in^2 and the other at 640000 cycles at 20 t/in^2. The conclusions are discussed.—C.V.

Problems involved in the development of programmed fatigue testing T. R. G. Williams and D. H. Hughes (*Engineer*, 1960, **210**, Oct. 28, 703–705) A review. Results show that the load sequence pattern adopted in a testing programme has an important effect on Miner's Σ (n/N) ratio, but contradictory results are obtained in tests on Al alloys and mild steel. Comparison of the relationship between random fatigue loading and the programme loading pattern recommended by Gassner shows that for Al alloys the programme test is a conservative estimate of the fatigue life in variable loading. Tests on Al alloys reveal a discontinuity in the S/N curve and this change in the mechanism of fatigue damage in Al may explain some of the contradictory results obtained between mild steel and Al-alloys.

Effect of the casting surface on the fatigue strength of cast steel H. Yoshitake (*Hitachi Hyoron*, 1960, **42**, Sept., 88–92; from *Japan Sci. Rev. Mech. Elect., Eng.*, 1960, **7**, Nov., 430).—C.F.C.

Quicker diagrams analyze steel fatigue M. D. Creech (*Prod. Eng.*, 1961, **32**, Feb. 13, 54–56) A suggested 'short cut' giving an approximate diagram which is suitable tor most ductile steels is considered and the conventional endurance diagram is compared with the approximate one. The method of construction, together with a working sample, is given.

Techniques and equipment for fatigue testing at very high frequencies E. A. Neppiras (*Proc. ASTM*, 1959, **59**, 691–709) Types of ultrasonic vibrators are described, and their advantages given. Specimen design, type of set-up, and relation of fatigue results obtained to those at lower temp. are discussed.

Random slip model of fatigue and Coffin's law A. N. May (*Nature*, 1960, **188**, Nov. 12, 573–574) A letter. A simple model is advanced from which the law can be derived.

Relation between the surface decarburization and the fatigue properties of plain carbon steel for machine construction. 5. On the fatigue strength of decarburized steel under multiple repeated stress at two stress levels T. Ueda and S. Ueda (*J. Japan Soc. Test. Mat.*, 1960, **9**, Aug., 520–528; from *Japan Sci. Rev. Mech. Elect. Eng.*, 1960, **7**, Nov., 428) [No abstract].

A method for determining the fatigue limit of metals by means of stepwise load increase test N. Enomoto (*Proc. ASTM*, 1959, **59**, 711–720) It is claimed that this method of fatigue testing reduces the number of samples required, and the time of tests, in comparison with conventional methods.

Fatigue tests on three cast irons at elevated temperatures R. P. Felgar (*Trans. ASTM*, 1959, **59**, 767–773) Direct stress and pulsating fatigue tests were carried out on Meehanite, Ni–Mo, and nodular cast-irons, and completely reversed push-pull tests on the latter pair. The temp. used ranged from 750–1000°F. Comparative results are given.

The effect of stress cycling on the static mechanical properties of SAE 4340 steel J. Marin, P. Borachia, and U. A. Rimrott (*Proc. ASTM*, 1959, **59**, 662–673) Heat-treated specimens were precycled under axial tensile loading to various percentages of the appropriate 'fatigue life'. The static properties of the specimens were determined, and compared with those obtained before pre-cycling. Sachs 'depletion of ductility' theory of fatigue was examined.

Some observations on the plastic work required to fracture stainless steel under cyclic loading D. E. Martin and J. Brinn (*Proc. ASTM*, 1959, **59**, 677–685) Controlled-load, low-cycle, axial fatigue tests were conducted on AISI type 347 stainless steel at 1000°F. Periodic records of the stress-strain behaviour of the specimens were obtained using an oscilloscope camera. The data are compared with results of prior investigations of strain cycling, and a tentative criterion of fatigue fracture is discussed.

Environmental effects in high temperature creep and fatigue M. R. Achter, P. Shahinian, and G. J. Danek, jun. (*ONR*–5, **2**; *PB* **161471**, 561–575) After a general review of various results obtained by other workers, and the explanations they advanced for their findings, the authors describe their own work on the relative effects of air and vacuum on creep and fatigue. At high temp. and low stresses creep strength is greater in air; at low temp. and high stresses vacuum conditions give the highest results.

Stability compared in joints of grains and sub-joints of iron in the cast zone submitted to thermal cycles S. Besnard and J. Talbot (*Compt. Rend.*, 1960, **251**, Dec. 5, 2706–2708) It is reported that tests made at 2 and 16 thermal cycles do not cause the disappearance of the polygonization of the iron after heating either at 200°C or 850°C.—S.H.-S.

X-Ray study of fatigue damage of metallic materials (change of phase transformation micro-stress in carbon steel caused by heat treatment due to ageing and fatigue) S. Taira and K. Honda (*Nippon Kinzoku*, 1960, **24**, (6), 331–335) Residual micro-stress caused by phase transformation was examined by X-ray back scattering. Stress is diminished by heating even at 300° and by ageing, especially during the first ten days. Material (0·78%C steel wire) tempered at 500° still showed residual microstress. Under alternating stress cycling the microstress fades, more rapidly during the first 10^4 cycles. A non-destructive method of detecting fatigue damage may be possible.—C.F.C.

Complex-stress creep of metals A. E. Johnson (*Met. Rev.*, 1960, **5**, (20), 447–506) A mathematical review, providing a survey of the progress made between 1940 and the middle of 1959 in experiment and theory as applied to structural design. Relaxation behaviour and plastic strain at high temp. tertiary creep, and the application of complex-stress creep theory to engineering structures are among phases of the subject investigated. Tabulated information is presented on rotating discs, tubes, pipes, and pressure vessels under internal pressure, pipe flanges, and flat plates. An appendix of notation used in the review, and a list of symbols are attached (80 refs).—S.H.-S.

Creep under rapid cyclic temperatures S. Taira and M. Ohnami (*Proc. 3rd Japan Congr. Test. Mat.*, 1960, 77–80 [In English]; from *Japan Sci. Rev. Mech. Elect. Eng.*, 1960, **7**, Aug., 173) Creep of low carbon and austenitic stainless steels was studied with rapid temp. changes. Apparatus is described. Creep strain can be predicted from that at uniform temp. on the concept of equivalent steady temp. Agreement with the values observed is fairly good.

The effects of nonsteady load and temperature conditions on the creep of metals S. S. Manson and W. F. Brown jun. (*ASTM, STP*, 1959, Dec., (260), 65–104) The problem is surveyed; 38 refs and 30 diagrams are included.

The extrapolation of families of curves by recurrence relations, with application to creep-rupture data A. Mendelson and S. S. Manson (*Trans. ASME*, 1960, **82D**, Dec., 839–847) A method using finite-difference recurrence relations is presented for direct extrapolation of families of curves and is illustrated by applica-

tions to creep-rupture data for several materials when it is shown that good results can be obtained without the necessity for any of the usual parameter concepts.—S.H.-S.

What you should know about creep rupture F. J. Clauss (*Mat. Design Eng.*, 1961, **53**, Jan., 89–100) (Manual No.179.) This is defined, stress, temperature, and time are considered, the use of sensitivity and scatter data briefly reviewed and the structure of three types of high temp. alloys is dealt with indicating how this will affect creep rupture as well as the effect of heat-treatment and cold work.—C.V.

Creep-rupture behaviour of notched and unnotched specimens of types 304, 316, and 321 austenitic stainless steels F. Garofalo (*Proc. ASTM*, 1959, **59**, 957–972) Temp. used were 1100 and 1500°F. All steels showed notch strengthening at 1500°F, but at 1100°F the rupture-time affected the initiation of notch strengthening or weakening.

Effect of environment on creep and creep-rupture behaviour of several steels at temperatures of 1000–1200°F F. Garofalo (*Proc. ASTM*, 1959, **59**, 973–982) Several ferritic and austenitic steels were tested in air, a purified mixture of He with 2%H_2 and *in vacuo*. Within the limits of the experiment, environment did not affect the results.

The measurement of Brinell hardness on alloyed castings (*J. d'Inf. Tech. Fonderie*, 1961, (122), Jan., 21–24) Rules for the taking of Brinell hardness tests, including the selection of suitable test pieces, are presented.—S.H.-S.

Hardness test shows decarburization Boeing Airplane Co. (*Steel*, 1960, **147**, Nov. 28, 118–120) A non-destructive hardness test, using a standard Rockwell hardness tester, in which variations in equipment are compensated for and depths to 0·018in can be measured, and the requirements for their operation are described, with two nomograms.—S.H.-S.

The effects of the roughness of the testing surface and of the opposite surface of the specimen on the Rockwell hardness S. Machida (*Trans. Japan Soc. Mech. Engrs.*, 1960, **26**, April, 578–583; from *Japan Sci. Rev. Mech. Elect. Eng.*, 1960, **7**, Aug., 173) [No abstract].

Proposal of the new hardness number and the relation between this number and the existing indentation hardness numbers J. Hashimoto (*J. Japan Soc. Test. Mat.*, 1960, **9**, May, 393–397; from *Japan Sci. Rev. Mech. Elect. Eng.*, 1960, **7**, Aug., 173) The new hardness number is determined independent of the shape of indenter and of load. By introducing the conception of the equivalent hardness number, the relation between the new hardness number and the conventional ones (e.g. Brinell and Vickers) is investigated.—C.F.C.

Orientation study on the workability of grey iron A. de Sy, E. Bodart, J. van Eeghem, and L. Czaplicki (*Fond. Belge*, 1960, **30**, Dec., 313–325) A tabulated series of tests and results upon eight types of grey cast iron assessed principally from the viewpoint of Brinell hardness.—S.H.-S.

Influence of small quantities of impurities on the restoration of mechanical properties of strongly cold-worked iron P. Morgaud and C. Messager (*Compt. Rend.*, 1960, **251**, Dec. 19, 2936–2937) A study made on the microhardness of samples of iron of differing purities: Armco iron, Armco iron purified with hydrogen electrolytic iron, and iron purified in the melt zone is presented.—S.H.-S.

Assessment of the strain-rate sensitivity of metals by indentation with conical indenters C. D. Davis and S. C. Hunter (*J. Mech. Phys. Solids*, 1960, **8**, Aug., 235–254) An impact indentation test is described and compared with hardness values using the same indenter. Non-ferrous metals, iron, and various steels were examined.

Application of statistical methods in the special steel industries (1st report). Principles of multiple correlation T. Araki and T. Morimoto (*Suihokwai-Shi*, 1960, **14**, Aug., 136–139) The use of the techniques is discussed and applied to the Jominy hardness curve as an example.

Edge cracking of a steel band conveyor G. C. C. Parker, T. Furman, and K. W. Chandler (*Engineer*, 1960, **210**, Dec. 30, 1099–1104) Cracking was found at the edge of rubber-covered bands without removal of the covering and traced to the fixed wing troughing rollers. Articulated rollers cured the defect.

Studies of the causes of the short life of tramway undercarriage assemblies S. Hoějš (*Hutn. Listy*, 1960, **15**, (10), 771–778) Excessive wear on Cr–V steel parts was found to be due to faulty wheel alignment.—P.F.

Cracking in welded joints of austenitic steel in C.E.G.B. power stations F. E. Asbury, B. Mitchell, and L. H. Toft (*Brit. Weld. J.*, 1960, **7**, Nov., 667–678) The type of steel involved was 18/8/1%Nb. Service histories, results of examination of failures, and of tests carried out to determine remedies are given.

Strain ageing of mild steel flat rolled products W. J. S. Roberts (*S. Wales Inst. Eng., preprint*, 1961, Jan. 12, pp.10) Effects in the tinplate and cold-reduced sheet processes are discussed in general terms. An outline of the concepts of Gensamer and Low (1943) is given.

The effect of phosphorus on strain-ageing in basic converter steel F. Erdmann-Jesnitzer and I. Karl (*Neue Hütte*, 1960, **5**, Nov., 660–665) Commercial basic converter steels of different phosphorus levels were studied with repsect to their susceptibility to ageing. The results show an age-retarding effect of phosphorus, and effect increasing with increasing P levels. The effect of P on the mechanism of strain-ageing is discussed theoretically.—T.G.

Structure and mechanical properties of iron–nickel–carbon martensites P. G. Winchell (*Massachusetts Inst. Tec., Abstracts of Theses*, 1958–1959, 88–89) Structure and mechanical properties of Fe–Ni–C martensites containing 0·01–1·0%C were examined. Potent solid-solution strengthening in as-formed martensite due to C as evidenced by increasing yield stress, occurs at low C levels and is independent of testing temp.; this suggests that Cottrell atm. formation is not a hardening mechanism. Between 0·4 and 0·8%C, very little additional solid-solution hardening is observed. Further strengthening in this C range is found during ageing; this reaches 50000 psi at 0·8%C. Solid solution hardening is thought to be due to the elastic interaction between the dislocation stress fields and the stress fields around random C atoms and not to the strength of atomic binding. The role of tetragonality is in itself of secondary importance. Precipitation-hardening is considered to be the cause of hardening which is observed with ageing.—C.V.

Extensibility and brittle fracture E. Steneroth (*Tek. Tidsk.*, 1960, **90**, March 4, 221–226) These properties are discussed, and the initiation of brittle fracture is considered (14 refs).

Co-operative study of brittle fracture in service (*Lastechniek*, 1960, **26**, Nov., 226–229) The Committee IX of the International Institute of Welding has for years been studying data relating to brittle fracture of steel in service and as a consequence a Sub-Committee D has been formed consisting of a small group of experts from various European countries under the chairmanship of Mr J. E. Roberts (UK) who are willing to provide advice and assistance regarding the manner of investigating any failures that occur. The report puts forward suggestions for the provision of desirable data for conducting such investigations.

An improved testing method to obtain the critical stress and arresting temperature of brittle fracture propagation M. Yoshiki, T. Kanazawa, and H. Itagaki (*Proc. 3rd Japan Congr. Test. Mat.*, 1960, 103–106; from *Japan Sci. Rev. Mech. Elect. Eng.*, 1960, **7**, Aug., 173) [In English] Critical stress is determined by initiating the crack in a region at low temp. and propagating it into a uniform temp. region, using static loading.

A study of crack propagation in hydrogen embrittled steel by a mechanical method E. J. Jankowsky and W. Beck (*ONR–5*, **2°** *PB* 161471, 493–508) The restraining load on a stressed hydrogen-embrittled notched C-ring decreases with increasing crack growth and the strain in a hollow bolt used for stressing the specimen is reduced accordingly. Time to failure and rate of crack propagation in Cd and Cr plated rings of ultra-high-strength steel were determined and the importance of triaxial stress state, surface concentration, and diffusion rate of H_2 as parameters controlling the rate of crack propagation discussed.

Study of plastic deformation and brittle fracture of steel and iron at low temperature G. T. Hahn (*Massachusetts Inst. Tech., Abstracts of Theses*, 1950–1959, 76–77) Tensile data, elastic limit measurements and metallographic observations of slip, twinning, and microcracks are reported for two steels and two heats of vacuum-melted ferrite over a range room-temp. to −250°. Grain size, sub-boundaries, pearlite, Mn, and temp. effect on yield and fracture behaviour and the theoretical implications are discussed. Grain dia. influences both yield and fracture characteristics; increase in grain size favour cleavages initiation and propagation. Variation in the amount of pearlite in the microstructure, Mn content, and degree of sub-boundary development appear to have little effect on fracture behaviour but Mn or heat-treatment which restricts the development of sub-boundaries, depresses the ductility transition temp. and promotes ductile behaviour.—C.V.

Shipbuilding from the view point of a steelmaker W. Dick (*Hüttenwerk Oberhausen, Tech. Ber.*, 1955–58, paper 34, reprint from *Fachzeitschrift 'Hansa'*, 1958, (38/39), pp.3; read at 2nd World Metallurgical Congress, Chicago, 1957, Nov.) This is a general account dealing with steel quality—particularly of course with brittle-fracture tendency—for shipbuilding with emphasis on very large tankers and weldability of the steels.—T.G.

Influence of hot-rolling conditions on brittle fracture in steel plate F. de Kazinczy and W. A. Backofen (*SSC*–126, 1960, Nov., pp.25) Notch-toughness in controlled rolling is found to be caused by micro-fissuring at the notch root and probably due to inclusions in a fibre structure too fine for ordinary techniques.

Studies of hot cracking in high-strength weld metals H. W. Mischler, R. E. Monroe, and P. J. Rieppel (*Weld. J.*, 1961, **40**, Jan., 1s–7s) The use of the freezing-cycle hot-tension machine is described and the effects of various elements on the tensile properties of SAE 4340 weld metals have been studied and indicate that if the total sulphur and phosphorus contents are kept below 0·025%, good hot ductility and hot strength are obtained and hot cracking is prevented. By a combination of light-microscope and electron-microscope examination an intergranular phase of unknown composition was identified as an iron–iron phosphide (Fe_3P) eutectic.—S.H.-S.

Brittle fracture characteristics of a reactor pressure-vessel steel E. T. Wessel and W. H. Pryle (*Weld. J.*, 1961, **40**, Jan., 41s–48s) Brittle fracture characteristics of Type ASTM A302B steel were determined with material from a 7-in thick plate for both the normalized condition and after heat-treatment consistent with thermal cycles encountered during the fabrication of a reactor pressure vessel. The heat-treated steel was found to be slightly more notch-sensitive and had a somewhat higher transition temp. than the normalized (as-received) steel. Compared with other steels studied under similar conditions, the A302B steel was found to be considerably more brittle-fracture resistant.—S.H.-S.

Potential-time curves obtained during the stress cracking of metals L. R. Scharfstein and C. M. Eisenbrown (*Nature*, 1960, **188**, Nov. 12, 572–573) A letter. 12%Cr martensitic steels in acid media in H_2-cracking conditions gave curves correlating with cracking phenomena. Explanations are advanced.

The effect of substructure on the cleavage fracture of iron crystals W. F. Flanagan (*Massachusetts Inst. Tech., Abstract of Theses*, 1958–1959, 74–75) The mechanical properties of Fe crystals were determined for various amounts of substructure (0, 3, 10% prestrain followed by annealing treatment); the metallographic and X-ray rocking curve techniques for determining crystal perfection were used and it was shown that substructure increases the brittle-ductile temp. of Fe crystals by 30–40°. The effect is saturated at 3% prestrain (10^{10} dislocations/cm^2) and is greater than the effect of crystal orientation or composition which has previously been reported. Twinning plays a role in the cleavage fracture by supplying the

local high stresses required for nucleating cleavage. A method of growing Fe single crystals is described in detail.—C.V.

Pressure vessel limits (*Engineering*, 1960, **190,** Dec. 9, 791–792) Radiation hardening and embrittlement of steels are discussed. It is pointed out that three things are needed to promote brittle fracture in a large steel structure, a notch, stress, and a temp. below the crack propagation temp. of the material. Various aspects of creep are reviewed, tests being made on Al grain refined steel of slightly different composition at varying temp. The two types of Na corrosion are examined and attention is drawn to the effect of Nb as a grain refining element. (On the occasion of the ISI Symposium, Nov.–Dec., 1960).—C.V.

Method for determining crack extension force Gc in high strength steel sheets and plates: tests of homogeneous aircraft armour plate $\frac{1}{8}$ inch thick H. E. Romine (*PB* 150144, 1958, July, pp.10; *NPG Tech. Memo NH*. T–22/58; from *US Res. Rep.*, 1960, **34,** Nov. 18, 624) The primary objective was the development of a test for determining Gc of steel sheets about $\frac{7}{64}$in thick and having a hardness of about 45 Rc. This is a progress report on procedure for testing flat sheet or plate material (tests on curved specimens may require more complex loading).—C.F.C.

Mechanical wear G. W. Rowe (*Appl. Mech. Rev.*, 1960, **13,** Nov., 787–790) An outline of testing methods and their assessment with a section on corrosive wear (24 refs).

A newly designed portable wear testing machine M. Okoshi and M. Mizuno (*Seimitu Kikai*, 1960, **26,** May, 247–253; from *Japan Sci. Rev. Mech. Elect. Eng.*, 1960, **7,** Aug., 173) Load is increased proportional to area in contact by an electro-magnet so that pressure is constant independent of depth of impression. Micro-wear is quickly detected microscopically. The apparatus weighs 6 kg and can be attached to large test-pieces.

The influence of speed on metallic wear W. Hirst and J. K. Lancaster (*Proc. Roy. Soc.* 1960, **259,** Dec. 6, 228–241) Wear of brass on steel was measured over the range 10^{-2} to 10^{3} cm/s using tracer elements. The mechanism remains the same over the whole range, and rates of transfer of brass to steel were determined showing that transfer is less at high speeds.

Recent experimental studies of solid friction F. P. Bowden (*Friction and Wear, Proc. Symposium, Detroit*, 1957; 1959, 84–109) The mechanism of friction is briefly summarized and the friction and deformation of solids at high speeds is considered, the apparatus for measuring this being illustrated. The method of introducing a thermocouple into a sliding interface so as to measure the temp. of rubbing surfaces is discussed and the friction of graphite at high temp. is reviewed with special reference to its behaviour with metals. Lubrication from the gas phase is considered; the effects of cutting Al with steel and Mo tools without lubrication, with H_2S gas, etc., being illustrated. The resolution of a molecular array in a crystal and the direct observation of dislocations in metals and non-metals is examined and examples of imperfections, moiré fringes, etc., are provided.—C.V.

A tentative model for the mechanical wear process R. Davies (*Friction and Wear. Proc. Symposium, Detroit*, 1957; 1959, 1–15) Five hypotheses are used: the rubbing materials receive energy in quanta all of which are of the same size; the quanta are added to the rubbing materials at domains that are randomly spaced over their surface; the quanta are added at moments which are randomly spaced in time; the quantized energy which is added at the surface diffuses continuously into the material at a known rate and sufficient energy in any one piece of the material causes that piece to detach itself in the form of a wear particle. These are discussed and experimentation shows a reasonable agreement between the theoretical experimental findings. Suggestions are made which may result in a better agreement being attained.—C.V.

Some metallurgical aspects of friction and wear L. F. Coffin, jun. (*Friction and Wear, Proc. Symposium, Detroit*, 1957; 1959, 36–66) The sliding process is described and the method of testing is discussed, the effects of material being divided into four classes: those couples having complete solid solubility; those possessing some solid solubility which may, or may not form intermetallic compounds; couples exhibiting a low solid solubility but which are capable of forming intermetallic compounds; and couples which do not alloy; the criterion in this last case being a low solubility when a lower melting component is in the liquid state. Examples are given and wear tracks are illustrated. The effect of a gaseous atmosphere (air, O_2, H_2, He, H_2O, and deaerated-H_2O) is discussed and the effects of temp. and liquid environment are also studied.

A theory of friction involving a microtopographical deformation index J. D. Huffington (*Wear*, 1960, **3,** Nov.–Dec., 473–476) The multiple junction theory of friction is further examined and a suggested new deformation index η is introduced. This is mathematically discussed and it is shown that surfaces can be classified into different kinds according to their η–A_r/A_i curves for different pressures (A_i=indentation area and A_r=the real area of contact) and these curves distinguish the properties of different surfaces independent of the material and of the average size of the asperities; the larger the η value, the smoother the surface; smoothness is defined as a surface with low average protuberance of asperities.

Friction, durability and wettability properties of mono-molecular films on solids W. A. Zisman (*Friction and Wear, Proc. Symposium, Detroit*, 1957; 1959, 110–148) The experimental techniques are described. Fatty amines and their derivatives, fatty acids, fatty alcohols, highly fluorinated compounds, terminally fluorinated alkyl derivatives, ω-bromoalkanoic acids, and chlorinated alkanoic acids are discussed (56 compounds) the method of preparing the film, etc., being indicated. The wettability of an adsorbed monolayer is defined by the nature and packing of the atoms at the outermost terminal of each polar molecule, the friction-reducing ability is the property of the whole molecule, both terminals, the over-all geometric shape, and the ability of the molecules to cohere or conform into a closely packed array.—C.V.

A study of the stick-slip process E. Rabinowicz (*Friction and Wear, Proc. Symposium, Detroit*, 1957; 1959, 149–164) All stick-slip processes are caused by the fact that the friction does not remain constant as a function of some other variable. This other variable may be distance, time, or velocity; each produces a form of oscillation. Various examples are given and the prevention is discussed the measuring and driving systems for the measurement being illustrated and discussed. Friction velocity curves for Ti/Ti, steel sliding on other materials covered by thin soap films, steel/steel (lubricated 100, 75, 60, 25% and unlubricated) and pure and filled Teflons and steel-filled Teflons, are shown.—C.V.

Study of critical velocity of stick-slip sliding B. R. Singh (*Trans. ASME, J. Eng. Indust.*, 1960, **82,** Nov., 393–398) The motion of a body sliding under boundary friction at a velocity slower than the particular critical velocity of the system proceeds in a discontinuous or stick-slip form. A theoretical and experimental study is presented. Since stick-slip occurs at a velocity lower than the critical, it is necessary in practice to have this critical velocity as low as possible; this can be achieved by narrowing the difference between the static and kinetic forces of friction, by increasing the stiffness-inertia ratio, and increasing the damping. The method of attaining these conditions is discussed. Apart from the use of grease lubrication instead of fluid lubricants to increase damping, this can be augmented by the application of special materials with high internal friction such as plastics or cast iron in the place of other metals. Fluctuations in drive velocity, or application of forced vibrations on the sliding system show that resonance vibrations enhance the stick-slip effect while high-frequency vibrations may reduce it.—C.V.

Sliding friction and wear under conditions of high velocity and high bearing pressures A. T. Robinson and T. D. Witherly (*ONR*–5, **2;** *PB* 161471, 701–711) Wear problems arising in the use of high-speed sledges are discussed, and design of sledge shoes, effect of type of material and the fundamental process by which wear occurs are considered.

Seizure of metal pairs during boundary lubrication C. L. Goodzeit (*Friction and Wear, Proc. Symposium, Detroit*, 1957; 1959, 67–83) In the simplest form of seizure the ability of metals to resist seizure during boundary lubrication is determined by the strength of the junction when bare metals meet bare metal; this strength is mainly determined by the alloying characteristics of a pair of metals. The ability of such a pair to form intermetallic compounds is a factor in their performance and even immiscible pairs can show the effect of differences in the binding forces that hold the atoms in the metals in their lattices. It is considered that this simple presentation may enable the more complex problems of friction and wear to be solved.—C.V.

A technique for investigating reactions between E.P. additives and metal surfaces at high temperatures F. T. Barcroft (*Wear*, 1960, **3,** Nov.–Dec., 440–453) Reactions between extreme pressure (E.P.) additives and metal surfaces at temp. up to 600° are studied. A thin metal wire is heated electrically while immersed in an E.P. oil and the wire temp. is obtained from the resistance/temp. characteristics of the metal. The rate and the extent of the reaction can be deduced from the change in the resistance in the wire with time. This method gives better results than the low temp. technique and the composition of the reaction products can be examined by X-ray diffraction techniques. The method is simple and rapid. There appears to be evidence that the ratings of the E.P. additives are independent of the steel used but the rate of reaction may vary widely with each steel. Also it is sometimes impossible to obtain wires in steels from which gears are made.—C.V.

Directional effects of friction M. Halaunbrenner (*Wear*, 1960, **3,** Nov.–Dec., 421–425) Various aspects of this problem are discussed and the influence of the direction of the machining processes (cutting and grinding) on wear is specially examined, experiments relating to this being described. The electrical contact resistance of metals is also affected by the direction of machining.—C.V.

Energy losses of balls rolling on plates R. C. Drutowski (*Friction and wear, Proc. Symposium, Detroit*, 1957; 1959, 16–35) Tabor's views that the energy required in rolling a ball on a plate is dissipated in hysteresis losses of the elastically strained metals are confirmed by the present work. The test apparatus and procedure are described and the variation in ball materials (Monel, cemented carbide, stainless steel, and Cr alloy steel) is examined and rolling force *v.* load curves are presented. Variation in plate roughness and orientation of lay, the effect of material homogeneity, variation of plate material, and the relationship between rolling force and material specific damping capacity are discussed. It is concluded that the average rolling force is not very dependent on surface roughness and orientation of lay and that the frequency distribution of rolling force peaks is a function of surface roughness, orientation of lay and material homogeneity and that these peaks are many times greater than the average rolling force. The equilibrium rolling force increases more rapidly with load in the range where plastic deformation occurs than it does where only elastic rolling is found.

Some measurements of rail-tyre adhesion R. T. Spurr (*Wear*, 1960, **3,** Nov.–Dec., 463–472) Adhesion between the wheels of a motorized bogie and the rails has been studied and measured under a variety of conditions. The effect of water, oil, and other contaminants is examined and the action of abrasives, detergents, and silicones has been studied with a view to increasing the adhesion. Silicones increase the adhesion of an oily rail because of their immiscibility with oil and their low surface tension, though since they are not boundary lubricants and, in the presence of water, very fine droplets remain, these can cause a marked fall in adhesion.—C.V.

The point of view of the metallurgist on pipelines transporting solids O. L. Bihet (**Centre*

Belge d'Etude et de Documentation des Eaux, 1960, March, (111), 76–81) Factors in erosive wear are reviewed, the metallurgical items being hardness, impact value, structure, and composition of which hardness is most important. Surface hardening and the use of internal linings are considered.

Instrument for the measurement of specular reflectivity in bright metal surfaces B. A. Scott (*J. Sci. Instr.*, 1960, **37**, Nov., 435–438) A simple modification of the gloss head for painted surfaces is described and is used to measure the surface quality of bright anodized Al in terms of specular reflectivity. This instrument possesses a high sensitivity and readily discriminates between surfaces of different appearance and good reproducible results have been obtained by two instruments. Although only used on Al, it should prove suitable for the assessment of bright finishes on other metals, although it is unsuitable for matt surfaces and those that are highly diffusing.—C.V.

Inspection problems solved by weaving trace optical gauging technique J. E. Baty & Co. Ltd (*Metalw. Prod.*, 1960, **104**, Dec. 28, 43–46) This new optical gauging technique enables profiles and dimensions to be checked despite inaccessibility. Magnification up to $\times 500$ is possible on a screen of 5in dia. irrespective of the size of the component. The principles are illustrated and discussed and examples of the application are given.—C.V.

'Black light' pin-points flaws in tube-conditioning line Algoma Steel Corp. Ltd (*Iron Age*, 1960, **186**, Nov. 24, 98–100) A series of continuous, semi-automatic operations, centrally controlled, whereby tubes up to 10in dia. and 40½ ft in length can be straightened, peeled, and after peeling, scarfed, and then tested, being turned beneath a battery of 'black lights', exposing seams, surface flaws, and other defects, with reduction in inspection needs, is described.—S.H.-S.

Report of committee A-6 on magnetic properties (*Proc. ASTM*, 1959, **59**, 156–157) The work of the committee and sub-committee during the past year is described.

A new magnetic test includes stainless steels M. Pevar (*Prod. Eng.*, 1961, **32**, Feb. 6, 41–43) A new version of testing with magnetic particles is discussed; this enables a permanent record to be kept; it also reveals the size of spot-weld nuggets in cold-rolled stainless and other steels. The solution containing the magnetic particles is sprayed or washed on to the part held in a magnetic field and the particles migrate to outline any magnetic discontinuities; visual inspection is made immediately. The water soluble plastic is then washed away unless a permanent record is required when the solvent is allowed to evaporate; the plastic film is then reinforced with pressure sensitive tape which is later stripped for storage. Several examples are illustrated. Testing for longitudinal and transverse cracks is also illustrated.

Testing colliery gear. III. Non-destructive testing by magnetic and penetrant methods (*Min. J.*, 1960, **255**, Nov. 18, 562–563) The concluding article in a series condensed from *NCB Bulletin* 60/219. Magnetic crack detection as a rapid method of non-destructive testing for ferro-magnetic materials to determine defects such as cracks, seams, blowholes, laps etc., and penetrant methods as a sensitive means of detecting the presence of surface discontinuities in all types of materials are briefly discussed, with advice as to the preparation of specimens to be tested.

An investigation of the effects of solute elements on magnetoelastic damping and coercivity in very pure iron R. E. Maringer and G. K. Manning (*PB* 149865, 1959, Oct., pp.24; from *US Res. Rep.*, 1960, **34**, Nov. 18, 623) Zone-refined Fe with single amounts of C was studied. Phenomena were observed attributed to C diffusion.—C.F.C.

Domain patterns on 'cube-textured' silicon iron sheet L. F. Bates and R. Carey (*Proc. Phys. Soc.*, 1960, **76**, Nov., 754–758).

Iron–cobalt permanent magnet alloys with additions of vanadium and chromium. I. Fundamental studies W. Baran, W. Breuer, H. Fahlenbrach, and K. Janssen (*Techn. Mitt. Krupp*, 1960, **18**, Nov., 81–90) The permanent-magnet alloy Vicalloy II of composition 52%Co, 13%V, balance Fe, has been modified by Krupp (52%Co, 8%V, 4%Cr, balance Fe) and is marketed under the name Koerzit T. It was established that the alloy consists of a fine-grain two-phase structure. The theory of the magnetization properties of these alloys is presented.—T.G.

Iron–cobalt permanent-magnet alloys with additions of vanadium and chromium. II. Uses H. Fahlenbrach (*Techn. Mitt. Krupp*, 1960, **18**, Nov., 91–96) The author discusses the fields of application of the permanent-magnet alloys of the Koerzit T type. As the raw materials from which the alloys are made are expensive the size of the magnets is rather limited, this is in line with the requirement that the alloy needs very high degrees of working for developing optimum magnetic properties. A number of examples are quoted and illustrated.—T.G.

Silicon iron: The influence of carbon and nitrogen on its magnetic properties (*Iron Coal Trades Rev.*, 1960, **181**, Oct. 28, 935–937) Specimens of very pure vacuum-melted Si-iron were examined and compared with similar ones to which controlled amounts of C and N were added; commercial alloys were also examined. The static hysteresis loss and coercive force of the very pure alloys were determined and it was found that the effect of N_2 is considerably greater than that of C; this is contrary to the accepted view. With the commercial alloy, it was found that N_2 addition had little effect on magnetic properties; with greater N_2 content the difference becomes more marked and the relationship between coercive force and N_2 content is linear, not a power relationship as was found in the pure (laboratory contaminated) specimen. The commercial sample contains 0·008%Ti and this modifies the effect of the N_2, TiN being formed. Photomicrographs show that in high purity Si-iron the N_2 is pptd. as acicular FeN, but when Ti is present in the high purity alloy the N_2 is pptd. as cubic particles of TiN and a more rounded FeN. In the commercial alloy containing Ti the FeN particles are also less acicular than in the high purity specimens. The two mechanisms by which impurities can affect the magnetic properties of these Si-irons are by the modification of the recrystallization texture and by the forming of inclusions which hinder wall movements of the magnetic domains and so increase the hysteresis loss.—C.V.

Temperature dependent magnetic contributions to the high field elastic constants of nickel and an Fe–Ni alloy G. A. Alers, J. R. Neighbours, and H. Sato (*Phys. Chem. Solids*, 1960, **13**, May, 40–55) The fundamental interaction between magnetic moments in a ferromagnet makes a contribution to the total energy. Therefore there should be a corresponding contribution to the elastic constants and to observe this effect the elastic constants C_{44}, $\frac{1}{2}(C_{11}-C_{12})$ and $\frac{1}{2}(C_{11}+C_{12}+2C_{44})$ are measured in Ni, and in an Fe–30%Ni alloy through their respective Curie temp. at high enough applied magnetic fields to eliminate the ordinary 'ΔE effect' which is associated with domain wall motion. The intrinsic magnetic interaction which should produce changes in the elastic constants upon passing through the Curie temp. was clearly observed in both materials. From these results, the first and second derivatives of the exchange energy are estimated. With Ni, this interpretation is relatively straightforward but in the Fe–Ni alloy the large volume magnetostriction makes the analysis of data difficult. The Ni measurements were extended down to 4·2°K but those of the alloy do not go beyond room temp. on account of the possible martensitic transformation.—C.V.

Magnetic resonance. Nuclear magnetic resonance of cores of iron 57 in the fields of yttrium and iron grains C. Robert (*Compt. Rend.*, 1960, **251**, Dec. 5, 2684–2686).—S.H.-S.

On the observation by Bitter's figures, of the elementary domains of samples of iron of different purities F. Dabosi and J. Talbot (*Compt. Rend.*, 1960, **251**, Dec. 19, 2933–2935) In this note, utilizing Bitter's figures, some observations on the Weiss domains of samples of iron of different purities are presented. This study bears particularly on electrolytic iron and on iron prepared by the zone refining method.—S.H.-S.

Experimental study on the critical diffusion of neutrons in iron M. Ericson and B. Jacrot (*Phys. Chem. Solids*, 1960, **13**, June, 235–243) The cross-section for the critical scattering of slow neutrons by Fe near the Curie temp. is studied and the parameters k_1, μ_1, and Λ introduced in the Van Hove's theory are measured for various temp. An equation is given together with an example and the results obtained for k_1 and μ_1 disagree with those found by other workers; they are however consistent with magnetic data. Comparing these results with other theoretical estimations it is found that the best fit is obtained with a model in which the second neighbours of an Fe atom are magnetically active and in which the magnetic electrons are described by the Heisenberg model.—C.V.

Certain anomalies in the electrical resistance of iron aluminium alloys in the neighbourhood of the iron corner P. B. Petrenko and P. P. Kuz'menko (*Ukrain. Fiz. Zhur.*, 1958, **3**, (6), 820–828) The relationship between resistance and the temp. and composition of the Fe–Al system was investigated at 16, 20, 25, 30, 40, and 50 at-%Al at temps. of 20–1200°C. For alloys containing 40 and 50 at-% the investigation was extended to the temp. of liquid O_2. Anomalies were found in the relationship for all alloys, a characteristic feature being an abrupt decrease in the temp. coefficient of resistance at certain temps. The effects described are associated with a change in the energy spectrum of the valence electrons, apparently due to changes in interatomic distances (15 refs).

Proposed recommendations affecting standards on steel (*Proc. ASTM*, 1959, **59**, 110–115; 116–123) New tentative specifications for ultrasonic testing and inspection of steel plates of firebox and higher quality, deformed billet steel bars for concrete reinforcement, leaded carbon steel plates, and quenched and tempered alloy steel bars, hot-rolled or cold finished, are presented. Revisions of various other tentative specifications that appear in the 1958 Book of ASTM Standards, Part I, are also given.

Ultrasonic energy (*Austral. Eng.*, 1960, **52**, Oct., 45–47) A general résumé of the many applications, with special reference to Branson products.—C.V.

Non-destructive testing. Ultrasonic methods. Part 2 W. E. Schall (*Instr. Practice*, 1960, **14**, Nov., 1181–1188) A mathematical and technical review, discussing the beam angle, absorption of ultrasonic energy, angle probe skip distance for flat sheets and for tubes with detailed descriptions of instruments, including the wall thickness gauge, the cathode ray tube trace, the flaw locating rule, and the interferometer and their uses and methods of operation.—S.H.-S.

Ultrasonic vibration paves way to greater design freedom (*Iron Age*, 1960, **186**, Dec. 8, 112–114) A combination of ultrasonics and abrasives, which shapes materials previously rejected as unmachinable and permits the use of solid sections instead of split components, is presented and its arrangement and operation is discussed.—S.H.-S.

Ultrasonic setup tests heavy sections Timken Roller Bearing Co. (*Steel*, 1960, **147**, Dec. 5, 104–105) A testing process by ultrasonic immersion, in a tank 30 ft long taking sections up to 12in square or 11in dia., and without special preparation of the test surface, used by Timken Roller Bearing Co. of Canton, Ohio, is presented and its operation described.

Testing colliery gear. II. Non-destructive testing by ultrasonic methods (*Min. J.*, 1960, **255**, Nov. 11, 534–535) The second of three articles condensed from *NCB Bull.*, 60/219. The use of ultrasonic waves on metals, whereby discontinuities such as slag inclusions, cracks, and cavities, giving rise to echoes which can be detected, with apparatus and techniques of flaw detection, is described.—S.H.-S.

Lattice strains and X-ray stress measurement M. J. Donachie, jun. (*Massachusetts Inst. Tech., Abstracts of Theses*, 1958–1959, 73–74) The behaviour of lattice strains in an aged 2024 Al alloy and in ingot Fe was investigated. Two sets of lattice strains were examined in each

specimen; they conformed to the strain ellipsoid being ∝ to the applied stresses. The elastic constants with the Al alloy were the same for both sets of lattice planes but slighlty different and greater than the macroscopic value; these differed from those obtained with ingot Fe and the different values of the latter reflected the anisotropic behaviour of the Fe-single crystals. As the applied stress increased, both sets of lattice planes in both materials, the limit of proportionality between the lattice strain and applied stress was the macroscopic yield point. The investigation led to the conclusion that stress data derived from X-ray strain measurements might be of greater value than the mechanical stress determination in considering the behaviour of metals under service conditions.—C.V.

X-Rays check plating thickness R. H. Zimmermann (*Iron Age*, 1960, **186**, Oct. 13, 84–87) A variety of procedures, based on the X-ray emission method, and handling a wide range of parts, is described, with evaluations of wear and porosity.—S.H.-S.

Radiographic standards to be developed for thin-section castings American Brake Shoe Co. (*Mat. Design Eng.*, 1961, **53**, Jan., 11) Experiments designed to illustrate defects commonly occurring in thin steel castings are described. Normal radiographic standards can only be applied to castings $> 0{\cdot}75$in thickness and the alloy steels investigated were AISI 4130, 4140, 4330, and 4340 with stainless steels 3471, 410, 430, and 17-PH. The defects to be examined were inclusions, cold shuts, shrinkage, cracks, porosity, hot tears, and misruns. The radiographs had to identify the size and nature of flaw and the several degrees of increasing severity. Ceramic moulds were used to minimize surface defects and mould design, rate of pouring, and metal temperature were varied to produce the desired type of flaw chills being used in some moulds while attachments were used to produce hot spots in order to vary shrinkage.—C.V.

Measurement of the Debye-Waller temperature factor for silver and α-iron C. W. Haworth (*Phil. Mag.*, 1960, **5**, Dec., 1229–1234) Measurements of X-ray diffraction over the range 286–1190°K were made. The characteristic temp. corresponded to 389°K.

X-Ray studies on ferrite-haematite solid solutions C. Okazaki (*J. Phys. Soc. Jap.*, 1960, **15**, Nov., 2013–2017) The system $NiFe_2O_4$–Fe_2O_3 is studied and the separation of α–Fe_2O_3 followed.

Testing colliery gear. I. Non-destructive testing by radiographic methods (*Min. J.*, 1960, **255**, Nov. 4, 498–500) The first of three parts of a condensed extract from *NCB Bulletin* 60/219, describing various methods of non-destructive testing. Part I, describing the radiographic method, presents the apparatus used and its assembly, with its interpretation, applications, the limitations, and the distinction between X-rays and gamma-radiography. The methods described are suitable for testing not merely colliery gear, but all types of mining gear of a similar nature.—S.H.-S.

Locating shrinkage cavities in ingots and blooms by means of gamma rays F. Khol and J. Schmied (*Hutn. Listy*, 1960, **15**, (10), 763–765) The technology of testing, using ^{60}Co is discussed on the basis of the authors' work, and conditions conducive to the introduction of the method on a works scale are analysed.—P.F.

Choice of gamma sources for industrial radiographic examinations D. Horvat (*Nova Proizv.*, 1960, (5), 258–261) Secondary ray effects and other factors limiting accuracy with ^{192}Ir, ^{137}Cs, and ^{60}Co are discussed. Range of thickness and exposure required are given. Below 15 mm of steel, no suitable source is available, ^{170}Tm being unobtainable with sufficient activity. For less than 30 mm an energy of $\sim$200 keV would be required.

A practical example of non-destructive testing with iridium-192 on a welded revolving tubular cement kiln at the building site at Karsdorf G. Tschorn, E. Becker, and F. Vorsprach (**Wissenschaftliche Zeitschrift der Hochschule für Schwermaschinenbau, Magdeburg*, 1959, **3**, (2), Nov., 215–223) A full account of apparatus, procedure, and safety precautions in the γ-ray examination of the welds.

Radiation damage in iron and steel D. R. Harries (*Nuclear Power*, 1960, **5**, March, 97–99; April, 142–145) The mechanism of change on irradiation and its effects on the tensile properties of pure iron and of ferritic and austenitic steels are outlined with tabulated data for ten materials. Notched bar, creep, and fatigue properties are recorded in the second part. The creep tests were carried out in the pile. Additional points receiving attention are mentioned (35 refs).

Further tests on the effects of irradiation on the properties of metals E. Schmid and K. Lintner (*Z. Metallk.*, 1960, **51**, Nov., 615–620) *Inter alia* the effect of neutron bombardment on the austenite–martensite transformation of a Cr steel of composition 5·40%Cr, 0·42%Si, 0·36%Mn, and 1·26%C was studied. It was found that at 10^{17} nvt martensite formation is promoted and that at 10^{18} nvt martensite is formed at as low as room temp., at the same time the residual austenite is stabilized so that the degree of saturation with respect to martensite is only low. This may be explained by an increased number of Frenkel defects which interact with one another, thus impairing the formation of martensite.—T.G.

Radioisotopes broaden field for non-destructive tests R. Hamlin (*Iron Age*, 1960, **186**, Dec., 127–129) The use of the radioisotope method in the nuclear-reactor field is described. The atomic-energy source, sealed safely in a camera, is surrounded by lead shielding. Finished radiographs monitor the internal quality of parts and defects show up due to their density differences.—S.H.-S.

The use of radioactive isotopes in welding research B. Žitňanský (*Zváranie*, 1960, **11**, (12), 350–353) A critical survey is made of several applications, based primarily on Soviet work published in the last few years.—P.F.

Electronic analysis of the Fe–Ni system S. Yamaguchi (*J. Electrochem. Soc.*, 1960, **107**, Dec., 1011–1012) An electron beam was utilized for heating the specimen as well as for diffraction and magneto-analysis. The temp. of the specimen can be controlled and thus it is possible to study the magnetic transition in the reported experimental method.—C.V.

Mobile linear accelerator probes big welds (*Metalw. Prod.*, 1961, **105**, Feb. 1, 63–64) The UKAEA is to use a mobile 4·3 MeV linear accelerator which will carry out high-intensity X-ray examinations of pressure vessels for nuclear power stations during construction. It can produce high-definition radiographs with relatively short exposure; at a distance of 30 ft, 10 ft of weld can be examined at each exposure. It was designed by Mullard Research Laboratories and is said to be superior to a ^{60}Co-radioisotope source or to conventional X-ray techniques.—C.V.

Report of the joint ASTM–ASME Committee on effect of temperature on the properties of metals (*Proc. ASTM*, 1959, **59**, 339–344) The activities of the committee are reported with a brief survey of projects.

The mechanical properties at elevated temperature of the several ferritic heat resisting steels S. Koshiba and T. Kunou (*Hitachi Hyoron*, 1960, **42**, June, 709–712; from *Japan Sci. Rev. Mech. Elect. Eng.*, 1960, **7**, Nov., 429) [No abstract].—C.F.C.

Elevated temperature mechanical properties of an austempered low-alloy steel during continuous heating D. P. Newman (*ONR–5*, **2**; *PB* 161471, 542–551) These tests were carried out under constant load and with continuous heating of the specimens. The object was to compare austempered with quenched and tempered structures, with regard to their use at elevated temp., only a limited comparison was found possible, due to lack of data.

Survey of various special tests used to determine elastic, plastic, and rupture properties of metals at elevated temperatures F. Garofalo (*Trans. ASME*, 1960, **82 D**, Dec., 867–881) Testing techniques employed in determining the elastic moduli (Young's modulus, shear modulus, and Poisson's ratio) at room and elevated temp., and depending on static or dynamic measurements, are described, and a comparison and an analysis of test results determined by these two methods are presented, the effect of composition, grain size, and various transformations in the elastic moduli or their temp. dependence being discussed. A review of techniques and experimental data on the effect of high strain rates on plastic and rupture behaviour of metals, and alloys at elevated temp. is presented, showing that recovery effects explain qualitatively the results obtained. A brief description of the stages of recovery is also presented. The variation of hardness with temp. is discussed for pure metals and alloys, including a description of a typical hot-hardness tester. The relationship between hardness and tensile strength, creep, and creep-rupture behaviour is briefly summarized and the use of the hot-hardness tester as a research tool for following solid-state reactions at elevated temp. is discussed.

Some observations on the extrapolation of high-temperature ferritic steel data R. M. Goldhoff (*Trans. ASME*, 1960, **82 D**, Dec., 848–854) A survey, in the course of which it is suggested that better estimates of long-time high-temp. material properties can probably be achieved by the use of some form of the Manson-Haferd parameter method as opposed to other simple methods currently in use. However, until reliable data to times of 50000–100000 h are produced for numerous alloys, none of the speculations accompanying the attempts to produce a much-needed answer can be checked for this important design problem.—S.H.-S.

High temperature strain gauges for structural testing R. Friedman (*ONR–5*, **2**; *PB* 161471, 636–648) A review of the present position in this field, giving the types of gauge available for different temperature ranges (11 refs).

Evaluation of cast alloys for use at high temperatures J. Salvaggi (*Rept. No. KB–1137–M–4*; *AD*–207503; *PB* 148242; from *US Res. Rep.*, 1960, **34**, Oct. 14, 477) Austenitic stainless steels with 17–20%Cr, 12–20%Ni, 2·5–5%Mo, and 0·27–0·48%C were modified with small amounts of Ti, B, Nb, and W, and cast into bars by the shell process. Some had excellent high-temp. strength properties, and adequate ductility. Some ferritic heats were also tested at 1200°F but had extremely low ductility.

Effect of working on heat-resisting properties of 316 L type steels and 16-15-6 type alloys. (On the function of nitrogen as an alloying element in heat-resisting materials. VIII) M. Okamoto, R. Tanaka, A. Sato, and S. Aoki (*Tetsu to Hagane*, 1960, **46**, Nov., 1559–1563) Hot–cold working gave increased hardness with 0·2–0·3%N_2 as did cold working. Deformation was mostly within the grains at lower temp. and at the grain boundaries with higher temp. Bending creep properties are reduced by cold work in presence of N_2.

'Intrinsic stress', σ_0, in the high temperature behaviour of metals E. Z. Stowell and T. S. Liu (*Nature*, 1960, **188**, Dec. 10, 933–934) A letter. An interpretation of the quantity is discussed.

Influence of stress concentrations at elevated temperatures G. Sachs, J. G. Sessler, and W. F. Brown, jun. (*ASTM, STP*, 1959, Dec., (260), 1–62) A discussion of the literature; some 83 refs are given and 65 diagrams.

Investigation of atomic mobility under axial compression at high temperatures in ferritic type alloys I. Ya. Dekhtyar and V. S. Mikhalenkov (*Ukrain. Fiz. Zhur.*, 1958, **3**, (4), 516–520) [In Ukrainian] Coefficients of diffusion under axial strain were determined on a ferritic alloy steel KB–7, containing 0·12%C, 12%Cr, 0·7%Mo, 4%W, and 0·2%V, at temp. of 900 and 1000°C, using the radioisotope ^{59}Fe.

An investigation of the effect of crystal lattice type and pressure on the self-diffusion parameters of iron in pure iron and in iron with low aluminium additions S. D. Gertsriken and M. P. Pryanishnikov (*Ukrain. Fiz. Zhur.*, 1958, **3**, (2), 255–264) The self-diffusion of iron in the pure metal and with additions of 0·27 and 0·39%Al was studied by the use of ^{59}Fe, in the α- and γ-regions (23 refs).

Identification of the diffusion of iron ions in magnetite employing markers D. Fuller (*Acta Met.*, 1960, **8**, Oct., 743–744) A letter. A critical discussion.—S.H.-S.

On the influence of plastic deformation upon the speed of intermetallic diffusion P. Chollet, I. Grosse, and J. Philibert (*Compt. Rend.*, 1961,

252, Jan. 30, 728–730) Triple-leaved bars of iron–nickel–iron have been submitted to deformation by alternate torsion (speed of shearing on the surface $d\gamma/dt = 6{\cdot}3.10^{-4}$ and $6{\cdot}3.10^{-3}S^{-1}$) during the annealing of the diffusion at 1200°C. The concentration–distance curves give evidence of no effect of the deformation on the speed of diffusion.—S.H.-S.

Effect of hydriding of steel on its endurance V. A. Titov (*Mezhkristallitnaya korroziya i korroziya metallov v naprazhennom sostoyanii*, 1960, Moscow, 257–268) Preliminary hydriding of a sample made from various grades of steel lowers its endurance both in air and in corrosive media. In a neutral solution with a protective current density of $0{\cdot}1A/dm^2$ it is possible to reach the conditional limit of endurance of a sample made from Armco-iron.

Hydrogen and austenite stabilization E. G. Ramachandran and C. Dasarathy (*Acta Met.*, 1960, **8,** Oct., 729–730) A letter. It is suggested that, while more experimental data on the effect of H_2 on the stabilization of austenite could undoubtedly be interesting, it would appear that the deactivation of the strain embryo in austenite, resulting in its stabilization, is unlikely by H_2, at any rate in the amounts present in normally heat-treated steels.—S.H.-S.

Influence of cold-reduction practice on hydrogen behaviour in enamelling steels R. M. Hudson, M. Kotyk, G. L. Stragand (*J. Am. Cer. Soc.*, 1960, **43,** Nov., 564–570) Hydrogen solubility (acid charged) in as-cold-reduced enamelling steel increased with increasing degrees of cold reduction. Normalizing such specimens, reduced the H_2 solubility but this heat-treatment only partially offset the marked effect of cold work, viz. for all steels H_2 saturation solubility was greater for normalized specimens that had had greater cold working than for normalized steels that had had less cold reduction. With increasing cold work, the H_2 desorption rate increased to a max. below 20% reduction; a further increase in reduction gave a decrease in desorption rate. Cold working of enamelling steel influenced both the behaviour of the acid-charged H_2 in this steel and the enamellability. With this increased cold reduction in the range 0 to ~75% there was a decrease in the intensity of the H_2 caused by groundcoat reboiling and the steel tended to develop delayed defects in direct white enamel coats. It was found that these defects could be diminished by previous normalizing and by the enamel firing process but essentially it was the previous cold reduction that controlled the H_2 behaviour.—C.V.

Effect of titanium, aluminium and oxygen on the solubility of nitrogen in liquid iron S. Maekawa and Y. Nakagawa (*Tetsu-to-Hagane*, 1960, **46,** Oct., 1438–1441) The solubilities of N_2 in Fe–Ti, Fe–Al, and Fe–O systems were measured at 1600–1700°C. Ti and O_2 increase N_2 solubility and Al decreases it. Equations for the effects observed are formulated.

On the nitrogen absorption of high Cr–Fe alloys with various chromium contents in nitrogen. (On the function of nitrogen as an alloying element in heat-resisting materials. VII) O. Miyakawa and M. Okamoto (*Tetsu-to-Hagane*, 1960, **46,** Oct., 1466–1474) Increase of Cr (in steel low in C and N) increased rate of N_2 uptake (at 1250°C in pure N_2). With 0·1%C, uptake was further increased, austenite formation occurred with acceleration of N_2 uptake. The promoting effect of C was higher than in alloys with more Cr which were mainly ferritic. Prealloyed N_2 delayed further uptake although it does tend to form austenite, this is more marked in higher chrome alloys and there were exceptions to this effect of N_2 already present. Heat treatment effects are described.

Effect of P on properties of 18Cr–12Ni–2Mo type heat-resisting steel. (Part I) N. Yamanaka, K. Kusaka, and A. Tonooka (*Tetsu to Hagane*, 1960, **46,** Oct., 1458–1465) Addition of P increased maximum hardness after ageing and decreased ageing time, apparently by accelerated separation of chromium carbides. Rupture strength increased but elongation and impact value fell. Addition of B improved rupture strength and ductility with 0·148%P.

Arsenic and phosphorus in high alloy Cr and Cr–Ni steels F. Beneš and D. Tlustá (*Hutn. Listy*, 1960, **15,** (12), 929–936) The effect of As (0·01–0·2%) and of P (0·025–0·1%) on the properties of heat-resistant ferritic chromium steels and on austenitic Cr–Ni was investigated. As in excess of 0·06% leads to a deterioration of heat resistance, corrosion resistance and weldability of the ferritic steels. Similar effects are found in the stainless steels as well, where an appreciable loss of notch impact strength is also associated with As contents exceeding ~0·06%. The effect of P, also in excess of about 0·05%, results in comparable detrimental effects.—P.F.

Silicon in steel (*Mech. World*, 1961, **141,** Feb., 53–54) A brief review of the effects of Si alone and in combination with other elements.

The manganese content of E11, E12 and E13 dynamo steels M. D. Nikitenko, P. P. Surin, and V. L. Varshavskii (*Stal'*, 1961, (1), 30–31) Variations in the content from various works were noted and the effects were examined. A reduction in Mn saved 1·5 kg Fe–Mn/t without any effect on properties or output and it is possible to avoid the use of Fe–Mn altogether if the bath before tapping contains not less than 0·08%Mn.

Effect of zirconium on the austenitic grain size in steel A. Adachi, K. Mizukawa, H. Omoto, and N. Hiraoka (*Osaka Univ. Fac. Eng. Techn. Rep.*, 1960, **10,** March, 471–480) The effect of Zr on the austenitic grain size refining and its grain coarsening temp. were studied in various atmospheres. The effect of N_2 alone on the austenitic grain size was also tested with electrolytic iron melted in a N_2 atmosphere. When Zr was added, the austenitic grain size was refined and its grain coarsening temp. became higher. Considering grain coarsening temp., amounts of inclusions which should be the cause of grain refining were calculated from thermodynamic data. It was considered that ZrN or ZrC were effective for grain size refining but ZrO_2 had little effect.

The effect of niobium on properties of 18 chromium–12 nickel austenitic stainless steel R. Nakagawa and Y. Otoguro (*Rep. Nat. Res. Inst. Metals*, 1960, **3,** July, 1–11; from *Japan Sci. Rev. Mech. Elect. Eng.*, 1960, **7,** Nov., 429) [No abstract].—C.F.C.

1960 Metal Selector (*Steel*, 1960, **147,** Oct. 10, 127–158) An up-to-date single source of information on metals and alloys, covering 20 categories of ferrous and nonferrous metals with more than 1000 product listings, and showing compositions, properties, and applications of metals and alloys. A valuable work of ready reference, with a mass of information clearly presented.—S.H.-S.

High boron steels and cast-irons J. Vrtěl (*Hutn. Listy*, 1960, **15,** (12), 945–950) Laboratory tests were carried out to ascertain the effect of B on steels and cast irons, B contents reaching 1·8% in cast irons and 5·5% in the steels. The influence of B on the physical and mechanical properties of the alloys was studied, and the nature of the phases formed was ascertained. In cast-irons, B dissolves in the cementite, or forms borocarbides $Fe_{23}(C,B)_6$ depending upon the B:C ratio. The stable boride Fe_2B is formed in steels if boron is present in excess of 1%. It was not found possible to dissolve this phase in the alpha-iron; consequently B additions exceeding 1% are unlikely to lead to improvements of the mechanical properties of steels or cast-irons. The effect of casting and heat-treatment on these boron alloys was studied.—P.F.

Two new series of steels Jones & Laughlin Steel Corp. (*Mat. Des. Eng.*, 1960, **52,** Nov., 9) An account of Jalloy–S and Jalloy–AR grades, respectively high-strength and abrasion-resistant.

Extra-deep drawing rimming steel J. Samson and G. Montlahuc (*Iron Coal Trades Rev.*, 1960, **181,** Oct. 21, 889–893; from *Rev. Mét.*, 1960, May, 387–395).

The high-strength steels—what they offer H. L. Kee (*Prod. Eng.*, 1961, **32,** Jan. 23, 54–61) About 100 steels are tabulated: Producer, ASTM designation, alloy, yield point, ultimate strength psi, %-elongation and composition, etc., being recorded. The special characteristics of the different groups are summarized.

What's a high-strength steel? C. L. Kobrin (*Iron Age*, 1960, **186,** Oct. 6, 168–170) A brief survey of the various strength groups, dividing them into high-strength low-alloy steels, high-strength structural steels, and, thirdly, super-strength or ultrastrength steels, defining their characteristics and properties.—S.H.-S.

Guide to high-strength constructional steels. Typical properties (*Iron Age*, 1960, **186,** Oct. 6, 171–175) The advantages of using high-strength steels, which are classified in a short guide list, are described, particularly as to strength, increased service life, economy of bulk, reduced weight, and increased pay-load, with a category of features and a comparison of specifications under three main group headings.—S.H.-S.

Superstrength steels pave way for new design concepts (*Iron Age*, 1960, **186,** Oct. 6, 176–177) Supersteels, which take over where high-strength steels leave off, are briefly defined and a representative list, with properties and nominal analysis is presented.—S.H.-S.

Ultrastrength steels move into vital industrial jobs (*Iron Age*, 1960, **186,** Oct. 6, 178–180) A group of six types of ultrastrength steels is listed, with their mechanical properties, features, and applications. It is suggested that apart from the aerospace and missile industries a wide field of uses is open for them in the aircraft industry proper; and also in broader fields, and advice as to their use, and works procedure for handling them, are given.

Low-alloyed, corrosion-resistant steels E. Herzog (*Corros. et Anticorros.*, 1960, **8,** Nov., 394–406) The effect of light or moderate additives to iron, from the point of view of resistance to atmospheric corrosion, the action of salt water, and certain mechanical reactions and stresses are examined and discussed, and the possible production of steels suitable for industrial construction as a result of such additions are suggested.—S.H.-S.

Classifying the precipitation-hardening stainless steels L. F. Weitzenkorn (*Reg. Tech. Meet. AISI*, 1958, 423–432) The early work on standard stainless steel is outlined and the three basic classes are stressed. In discussing precipitation hardening, the early work on duralumin is recalled in which the Al and Cu used in the alloy are precipitated as a Cu–Al compound, the hardness and mechanical strength being due to a dispersal of submicrographic particles in the atomic lattice. In stainless steels, the precipitated particles are generally considered to be compounds which form because the solubility of the hardening agent, dissolved in austenite, decreases as the temp. drops. When this occurs, the hardening agent is thrown out of solution in the metal and forms a submicroscopic precipitate dispersed throughout the structure of the steel. These steels are divided into three groups: I, martensitic as solution-treated and as-aged (Stainless W, 17–4 PH) using Ti and Cu respectively as hardening agents; II, austenitic as-solution-treated and martensitic as transformed and aged (17–7 PH, PH 15–7, Mo, Am 350 and 355); III, austenitic as-solution-treated and as-aged (17–10 P and HNM), these steels containing P. A possible fourth group is discussed to cover alloys that have a duplex austenite–ferrite structure in both solution-treated and aged conditions. V2B (Cr–Ni–Mo–Cu) is an example.—C.V.

Corrosion- and acid-resistant steels and their surface treatment W. Grass (*Mitt. Forschungsge, Blechverarb.*, 1960, Dec. 15, 297–305) The development and uses of corrosion resistant steels are reviewed. Passivity is shown to be a criterion for corrosion resistance. The importance of surface condition is stressed and polishing, brushing as well as grinding of steels is discussed from the point of view of corrosion resistance.—R.P.

New stainless steel offers three benefits W. J. Long (*Steel*, 1961, **148,** March 27, 178) A new steel, designated Uniloy 303MA, which is claimed to offer better machineability, improved corrosion resistance, and excellent surface finish, is presented.—S.H.-S.

Stainless steel containing boron manufactured on trial E. Miyoshi and T. Yukitoshi (*Sumi Met.*, 1960, **12,** April, 415–427) [In Japanese] Stainless steels containing up to 6·1%B were melted, forged, and rolled. Those

containing less than 2 %B can be forged to bar and plate but not those containing more than 3%. With increasing boron content, toughness decreases and brittleness increases.—R.S.F.C.

Stainless steels, other corrosion resistant alloys used more widely (*Mat. Design Eng.*, 1961, **53**, Feb., 112–113) The all-round corrosion resistance of types 304 and 316 account of the general use of these, 316 being superior in some environments, especially those resulting in pitting. The present trend is toward the use of the low C-grades, 304L and 316L which minimize carbide precipitation problems. Welding or operations at 800–1 500°F tend to precipitate Cr carbide which promotes corrosion with some acids; this is solved by addition of Ti and Nb (types 321 and 347). The relatively small use of types 317, 302, 321, 347, and the 200 and 400 series is commented on, but the application of the 200 steels to food processing is considered. The use of Al, Incoloy (petroleum processing equipment), and 60Cr=40Ni alloy for the same use and 42Ni=21·5%Cr for plant evaporators or phosphoric acid equipment are suggested while examples are given relating to cathodic protection (26 refs).

The present state of ship plate specifications A. F. Mohri (*Can. Min. Met. Bull.*, 1961, **54**, Feb., 157–162) A brief review of current British, American, and Canadian practice, with reference to ship plate composition and production, is presented.—S.H.-S.

Tool steels B. L. Averbach (*Climax Molybdenum Company, pamphlet*, 1960, pp.32) The tool steels are classified (type, composition, application, etc.) in tabular form, being divided into water-hardening, shock-resisting, cold work (oil and air hardening, high-C, high-Cr), hot work, high-speed (Mo and W base), and stainless steels. Carbides in alloy steels (type, details of lattice, etc.), and other relevant data are discussed. Hot hardness and dimensional behaviour are also considered (32 refs).—C.V.

High-chromium steels containing titanium and nitrogen as replacements for steels 1Kh18N9 and 1Kh18N9T D. A. Odesskii and M. F. Alekseenko (*Stal'*, 1961, (3), 262–266) Steels Kh17T and Kh28T with respectively 0·08%C, 0·56%Si, 0·55%Mn, 0·4%Ni, 17·33% Cr, and 0·46%Ti; and 0·09%C, 0·46%Si, 0·54%Mn, 25·05%Cr, and 0·47%Ti are tested as replacements for grades containing Ni. Very full accounts of mechanical and anticorrosive properties are given. The former is unsuitable for welding but the latter is satisfactory. Uses are indicated.

General purpose properties are possibilities of application of the 12% chromium containing hot strength steel G. Krüger (*Neue Hütte*, 1961, **6**, March, 131–138) The alloying elements, constitutional diagrams, and microstructure are explained and recent developments in the properties of 12%Cr steels are described.

The metallurgy of 5% chromium high strength steels G. A. Roberts (*Rev. Mét.*, 1961, **58**, Jan., 65–77) This air-hardening steel appears to be the best available for ultra-high strength at room temp., (with higher impact strength and ductility at the 220 000–300 000 psi tensile range than low alloy steels and a high fatigue strength), or for elevated temp. stability up to 1 000°F. It has a high-strength to-weight ratio at 400–1 000°F, surpassing that of heat-treated Ti alloys (19 refs).

Alloy research: Development of new ultra-high strength Cr–Mo–V steels and tool steels (*Can. Mines, Research and Special Projects for* 1960, 1961, 1–2) This steel showed properties superior to others examined. The thermal fatigue properties are being examined in a special apparatus designed by the laboratory. The samples are subjected to rapid heating cycles under static load and the number of cycles to failure is considered to be a measure of hot-work suitability. Early trials show this test to be comparable to actual service tests. In the latter, AISI H 13 steels is superior to H 26; in the test H 13 withstood 1 650 cycles but H 26 failed after 800 cycles. Confirmatory work has also been carried out on other steels.

Alloy research: Development of steels for use at low temperatures (*Can. Mines, Research and Special Projects for* 1960, 1961, 2–4) Further work has been carried out on plain C-structural and low alloy steels for use under the indicated conditions. A Nb-bearing steel has been specially examined. The most significant result was obtained with a 1¼in plate in which normalizing dropped the Charpy V-notch 15 ft/lb transition temp. from 43° in the as-rolled condition to −59° in the normalized condition with no significant loss of yield strength. Further experiments are described. Another series of experiments shows the effects of Nb, Zr, and Ti on dislocation pinning. Samples of 100 g electrolytic Fe were melted and alloyed in a vacuum. The material was cold swaged and drawn to 0·125in dia. wire. Procedures to obtain a wide range of grain size were developed and these were examined using the Chevenard microtensile specimen. Testing and checking of the calibration of the microtensile machine is being undertaken.—C.V.

Weldable high strength stainless steels J. I. Morley (*Proc. Eng. Materials and Design Conference, Feb.* 1960, *London*, 1960, P, pp.26) These are modifications of the 18%Cr–8%Ni type with similar corrosion resistance but higher hardness and strength. This paper is divided into two parts: I. Low-carbon martensitic steels, and II. Semi-austenitic or controlled-transformation stainless steels; in each case the various treatments, mechanical and special properties are discussed.—C.V.

Research and control laboratory, Bhilai (*Sci. Eng.*, 1960, Nov.–Dec., 164–168) This is divided into chemical laboratory for chemical and spectrum analyses, metallurgical department, metallographic and macroetching, X-rays, heat-treatment, corrosion and mechanical testing, radioactive isotopes laboratory, and laboratories for the study of sintering, refractories, fuel and lubrication, instrumentation, and electrotechnical problems. This was planned by the USSR. Some of the work to be carried out is further discussed.—C.V.

METALLOGRAPHY

The structural metallurgy of steel K. W. Andrews (*Iron Steel*, 1961, **34**, March, 82–89) The foundations upon which the argument is based are: (1) Steel is iron containing a number of other elements (a) in liquid solutions above the mp, (b) in solid solution in austenite and ferrite, (c) combined as carbides, nitrides, etc., (d) as non-metallic inclusions. (2) The elements can be divided simply into three groups, (a) deliberately added to produce certain effects (Ni, C), (b) incidentally present but accepted and controlled (Si and Mn in many steels), (c) also incidentally present but to be kept as low as possible (S, P, H_2, and Θ). Each of these elements must be taken into account and the general aim of treatment includes the following steps: (a) Precise evaluation of the freezing point in terms of composition, (b) evaluation of mp (solidus) in similar terms, (c) calculation of transformation range at high temp. (austenite to ferrite), (d) inclusion with 'c' of any carbide pptn. that may occur, (e) calculation of subcritical transformation behaviour, (f) calculation of mechanical properties in terms of parameters derived from 'e', (g) alternatively calculations from chemical composition for other conditions (creep strength of austenites or ferrites in terms of alloy content, and (h) calculation of low temp. impact transition temp. in terms of composition and treatment. A most informative diagram is presented in connexion with these considerations. A very detailed discussion follows.—C.V.

The Automet in the laboratory Buehler Ltd (*AB Met. Dig.*, 1961, **7**, Jan., 4–9) The apparatus and its operation are briefly described.

Effect of a small amount of V, Ti, and Zr addition on carbide precipitation in Hadfield steel heated after solution-treatment. (Study on austenitic high manganese steels. II) Y. Imai and T. Saito (*Tetsu-to-Hagane*, 1960, **46**, Oct., 1451–1458) Micrographic and dilatometric studies were made of isothermal carbide precipitation. Transformation points were altered and growth rates were changed considerably by Ti or Zr. In the presence of inclusions, pearlitic constituents were deposited at an increased rate and the effect of Ti or Zr was attributed to nitride formation. Yield strength was increased by all three elements but mechanical properties were reduced by heating after solution treatment.

On carbides in Cr–Mo–V hot-working tool steels. (Study on carbides in commercial special steels by electrolytic isolation. X) T. Sato, T. Nishizawa, and K. Tamaki (*Tetsu-to-Hagane*, 1960, **46**, Nov., 1549–1449) The separation and transformation sequences of carbides during the tempering of these steels were worked out. Four processes appear to proceed simultaneously.

Oxide inclusion in ferro-chrome G. Siebert and E. Plöckinger (*Techn. Mitt. Krupp.*, 1960, **18**, Nov., 44–53) The relationship between the level of inclusions in the ferro-chrome and the inclusions in the steel produced with the Fe–Cr was studied. It was found that the Si content of the Fe–Cr is rate-determining, particularly with respect to the type of inclusion. The limit of the two-phase inclusions lies around 0·2%Si.—T.G.

The potentiostatic isolation and analytical study of inclusions in ferro-chromes C. Ilschner-Gentsch (*Techn. Mitt. Krupp.*, 1960, **18**, Nov., 54–63) Commercial ferro-chromes with between 1·27 and 4·33%C were used for the study of the structure and composition of the inclusions resulting in steels to which these ferro-chromes were added. It was found that the inclusions consisted mianly of an iron–chromium solid solution and the carbide $Me_{23}C_6$, sometimes the carbide Me_7C_3 was also observed in minute quantities. There was a marked difference with respect to the inclusions between sand-castings and metal-mould castings owing to the Si content of the former. X-ray analysis showed that the Cr was present in the silicon-low samples as Cr_2O_3 and Cr_3O_4.—T.G.

The stability of europium oxide in silicon-bearing stainless steel C. F. Leitten, jun. (*ORNL–*2946, Sept., pp.94; from *Nucl. Sci. Abs.*, 1960, **14**, Nov. 30, 3016) The stability of Eu_2O_3 dispersed in Si-bearing stainless steel powder compacts was studied in the temp. range 900 to 1250°C. The effects of Si content of the stainless steel powder, oxide conditioning treatment, and heat-treating time and atmosphere were also investigated.

On the precipitation of Laves phases in modified 12%Cr steels J. Koutský and J. Ježek (*Hutn. Listy*, 1960, **15**, (11), 864–867) In 12%Cr steels containing either Ni (0·4%), Mo (1·84%), or Ni (0·17%), W (3·42%), and Co (5·50%), intended for service at high temp., conditions favouring the precipitation of Laves phases of the type Fe_2Mo and Fe_2W were studied. Formation of Fe_2Mo is favoured in steels having a low Mo:C ratio from which V is absent, and which are structurally heterogeneous. Fe_2W formation is favoured by the presence of high Co concentrations, in steels having a homogeneous sorbitic structure, if the W:C ratio is low. Co appears to catalyze the formation of Fe_2W.—P.F.

Precipitation-hardening of low-carbon steels M. Klesnil and P. Ryš (*Hutn. Listy*, 1960, **15**, (11), 867–876) A mild steel containing 0·05%C and 0·0042%N was used in an electron micrographic study of precipitation hardening. A carbide phase is observed to form, and is responsible for the hardness. The rate of formation of the carbide is controlled by a process having an activation energy of 18 k-cal/g-atom, which suggests that the diffusion of carbon is rate-determining. Precipitation hardening following prior cold-work leads to much higher hardnesses than without cold-working, and a greater structural stability of the steel is obtained. Both effects are explained in terms of enhanced nucleation rates of the alpha solid solutions.—P.F.

Study of the formation and precipitation of deoxidation products M. Wahlster and E. Plöckinger (*Techn. Mitt. Krupp*, 1960, **18**, Nov., 64–80) The study conducted in the laboratory and on 3-t baths brought about new knowledge on the processes involved in the formation of oxide inclusions and their precipitation. The oxide inclusions form via a liquid phase and it is for this reason that they are able to coagulate; the degree of coagulation depending on certain conditions during formation and on the physical properties of the oxides, as well as on the movement prevailing in the steel bath (25 refs).—T.G.

Experiments to determine the radiation of UN dispersions in stainless steel J. E. Gates (*BMI–*1446, 1960, June, pp.29; from *US Res. Rep.*,

1960, **34,** Nov. 18, 660) [No abstract].—C.F.C.

Austenitic grain-size: its determination and control A. Adachi (*J. Japan Soc. Test. Mat.*, 1960, **9,** Aug., 504–507; from *Japan Sci. Rev. Mech. Elect. Eng.*, 1960, **7,** Nov., 427) (No abstract].—C.F.C.

Secondary recrystallization in metallic double or multi-layers H. G. Baer (*Z. Metallk.*, 1960, **51,** Nov., 650–655) Metal foils or thin sheets were used for the recrystallization experiments. The foils or sheets of different metals were placed on top of one another (the surfaces were cleaned but not specially prepared) and heated in a furnace in an atmosphere of H_2. It was found that during secondary recrystallization the crystals of one metal migrate into the matrix of the other in contact with them. Materials which under normal conditions do not show secondary recrystallization can be induced to do so by the presence of another metal that does show this phenomenon.—T.G.

Phase transformations in steels during electrotempering V. N. Gridnev and V. I. Trefilov (*Ukrain. Fiz. Zhur.*, 1958, **3,** (6), 796–801) [In Ukrainian] The effects of high heating rates on phase transformations are examined on C steels subjected to electrotempering. Tempering effects are displaced to higher temps with increased heating rates. The mechanism of the results observed is discussed (12 refs).

The solidification of ferrous alloys and of industrial grey pig iron J. Obrebski (*Mét. Constr. Mécan.*, 1960, **92,** Dec., 1001–1011) Graphitization pressure is defined, the influence of oxygen is explained, and numerous examples of samples obtained are discussed.

Malleable iron-graphitization kinetics G. Sandoz, B. F. Brown, and W. A. Pennington (*Mod. Castings*, 1961, **39,** Jan., 93–103) The effect of traces of Bi, Sb, Sn, Pb, Cd, and Zn on the kinetics of each of the three graphitization processes critical to the malleablization of iron were studied.

An investigation of abnormal structure in a 1·5% Mn mild steel B. J. Nield (*JISI*, 1961, **199,** Sept., 22–26) [This issue].

Structural changes occurring on heat-treating cast 13%Cr steels S. Drapal (*Hutn. Listy*, 1960, **15,** (12), 961–971) Austenite decomposition and other structural changes occurring above the A_1 point were studied in 13%Cr steels containing 0·05 to 0·34%C.

Stabilization of the martensitic transformation in iron-nickel alloys J. Woodilla, P. G. Winchell, and M. Cohen (*MIT Tech. rept.* 2 *AD* 226382; *PB* 148565; from *US Res. Rep.*, 1960, **34,** Oct. 14, 481) An Fe–Ni alloy with 0·007%C in rods 2·5in × 0·074in dia. was used. These were austenitized in sealed tubes and quenched, some being previously decarburized in H_2. The decarburized specimens showed no stabilization.

On the crystallography of martensite: the '{225}' transformation in alloys of iron C. M. Wayman, J. E. Hanafee, and T. A. Read (*AFORSR-TN*–60–525; *PB* 148874; from *US Res. Rep.*, 1960, **34,** Oct. 14, 477) For an accurate study of the transformation it is necessary that the martensite habit plane and orientation relationship for a single plate be determined. These observations are especially needed for the '{225} A' transformation for which this determination had not previously been made. The presence of martensite side-plates was observed. The nature of these plates is uncertain at present. The findings point to the need for a microscopical examination of the austenite-martensite interface.

Investigation of alloys of iron with manganese and chromium A. T. Grigor'ev and D. L. Kudryavtsev (*Izvest. Akad. Nauk. Fiz. Khim. Anal.*, 1946, **16,** (2), 82–99) The austenitic region of the system Fe–Mn–Cr was studied by dilatometric analysis by differential heating curves, hardness, electrical resistance, and microstructure. Within the limits of 0 to 10–12%Mn the transformation was observed, which was accompanied by a significant thermal effect, a sudden reduction in volume on heating, and an increase on cooling (16 refs).

Equilibrium diagram of the ternary system iron-chromium-aluminium I. I. Kornilov, V. S. Mikheev, O. K. Konenko-Gracheva, and R. S. Mints (*Izvest. Akad. Nauk. Fiz. Khim. Anal.*, 1946, **16,** (2), 100–115) The fusibility diagram of part of the Fe–Cr–Al system has been established by the methods of physical-chemical analysis. The regions have been determined of distribution of FeCr and of the $\alpha \rightarrow \gamma$ transformation in the ternary system. Several other conclusions were reached (48 refs).—A.I.P.

Solubility of carbon in iron silicon and iron-silicon-manganese alloys (*Can. Mines, Research and Special Projects for* 1960, 1961, 13) Several methods for the production of a 2·75%Si 1%Mn pig iron were investigated; these contained > 3·9%C and the max. temp. was 1 350°. Equilibrium solubility for a Fe–Si–Mn alloy of this composition is 3·9%. It was found that by adding Mg and graphite during the recarburization and before the alloys were added, the equilibrium could be attained and even exceeded. If 75%Fe–Si was added to an iron almost saturated with C, the equilibrium value was greatly exceeded and in this case no heat was lost upon the addition as the interaction is exothermic. This latter method is to be carried out on a production scale.—C.V.

The system iron molybdenum-silicon R. Vogel and R. Gerhardt (*Arch. Eisenh.*, 1961, **52,** Jan., 47–56) An investigation of the phase diagram of this system is described in detail, particular reference being made to the properties of the following three ternary phases: Fe_2MoSi_2, Fe_3Mo_2Si, and Fe_2Mo_2Si.

CORROSION

Corrosion problems and their treatment. 2. (*Corros. Prev.*, 1960, **7;** *Corros. Eng.*, **2,** Oct., iv–viii) The causes of corrosion in steel water-storage tanks are considered, and remedial measures for various forms of tank are described.

Problems of high temperature corrosion in modern process plants J. I. B. Rutherford (*Met. Fin. J.*, 1960, **6,** March, 95 101, 111) A general review. Conventional corrosion and high temp. corrosion are similar except that in the latter case a direct chemical compound formation is involved and not an ion exchange. This minimizes the effect of hydrogen which is of primary importance in aqueous corrosion. However, the same phenomena are encountered, general attack, localized pitting and catalytic effects at cracks and crevices and where stresses, specially repetitive stresses, are involved, the problem of fatigue must be considered.—C.V.

Selective removal of chromium from Type 304 stainless steel by air-contaminated lithium R. E. Seebold, L. S. Birks, and E. J. Brooks (*Corrosion*, 1960, **16,** Sept., 468t–470t) The authors have studied the corrosive action of high-purity and air contaminated Li on type 304 stainless steel in non-isothermal closed systems between 800° and 1 500°F. The initial step in the corrosion caused by air-contaminated Li is a preferential leaching of Cr.—G.F.

Compositional effects in the corrosion of type 347 and 316 stainless steel in chemical environments C. P. Dillon (*Corrosion*, 1960, **16,** Sept., 433t–440t) Using statistical analysis, the author considers the effects of composition variations on the corrosion resistance, as indicated by the Huey test, of Nb-stabilized and Mo-bearing stainless steels. The practical implications of the results are discussed.—G.F.

Comparative accelerated tests for corrosion resistance of electrolytic zinc and cadmium coatings on steel T. Biestek (*Prace Inst. Mech.*, 1958, **7,** (22), 20–41) The tests were carried out in various ways on coatings of thicknesses of 1 to 30 μ. In an atmosphere of industrial gas, in salt spray and in a spray of different salt solution; and by periodical immersion in NH_4Cl solution. As a result it was concluded that the interdependence of corrosion resistance and coating thickness was established and corrosion resistance compared. It was found that zinc coatings obtained from a cyanide bath have a higher corrosion resistance than those of like thickness from an acid bath. When comparing zinc and cadmium coatings from a cyanide bath their corrosion resistance depends largely on the type of corrosive medium so that it cannot be said generally that Cd is superior to Zn.

Quarterly report of the solution corrosion group for the period ending July 31, 1958 J. C. Griess, H. C. Savage, R. S. Greeley, J. L. English, S. E. Bolt, S. R. Buxton, D. N. Hess, P. D. Neumann, E. S. Snavely, W. C. Ulrich, and N. E. Wisdom (*CF*–58–7–132, 1958, July, pp.36; from *Nucl. Sci. Abs.*, 1959, **13,** Jan. 15, 23) A number of loop runs were made to determine the chemical stability of possible nuclear fuel solutions. Among the many results reported it was shown that the removal of O_2 from uranyl sulphate solutions caused severe corrosion in stainless steel loops. Some stress-corrosion cracking of austenitic stainless steel specimens was observed in the presence of chloride. Treatments to inhibit corrosion cracking of stainless steel are described.

Behaviour of structural materials exposed to an organic moderated reactor environment N. J. Giosetti and H. E. Kline (*NAA–SR*–2570, 1959, Oct., pp.44; from *Nucl. Sci. Abs.*, 1959, **13,** Dec. 31, 2997) The behaviour of various structural materials including 1020 carbon steel 304 and 410 stainless steel, 4130 alloy steel, Al and Mg in the reactor was determined. In-pile specimens examined were exposed to measured integrated neutron fluxes. The results are given.

Stress, crevice, galvanic and uniform corrosion of austenitic stainless steels and carbon steel in high temperature boiler feed water: a literature review R. B. Richman (*HW*–54879, 1958, Feb., pp.12; from *Nucl. Sci. Abs.*, 1959, **13,** Jan. 15, 25) A bibliography (89 refs).

A method for the investigation of the corrosion of metals under condensation conditions I. L. Rosenfeld and K. A. Shigalowa (*Werks. Korros.*, 1960, **11,** Nov., 707–708) A device is described for determining the amount of moisture condensed on the metal surface during corrosion tests in given temp. conditions, and the corrosion to be expected under these conditions.

First reports on corrosion tests on electro-deposited coatings for steel parts used in electrical ship fittings T. Biestek, T. Lipski, and R. Bucko (*Prace Inst. Mech.*, 1958, **6,** (23), 87 92) Since no information is available on this topic of a consistent character, research work was done to establish the type and thickness of the electro-deposited coating which gave satisfactory protection. Tests were conducted for a period of two years on a ship sailing between Poland and Southern China. Test panels were coated with Zn, Cd, passivated Zn, passivated Cd, and laminated Zn Cd. The results were that Cd coatings showed better corrosion resistance than did Zn coatings; passivation of Zn and Cd increased their corrosion resistance in marine conditions; corrosion attack was different in various parts of the ship, and the durability of protective coatings should be related to the expected life of the protected parts.

Corrosion of steel in the presence of H_2S J. J. Point (*A/CONF*.15/*P*/127, pp.13; from *Nucl. Sci. Abs.*, 1959, **13,** April 30, 902) Mechanism of the acceleration of steel corrosion in the presence of H_2S was studied by means of ^{35}S (distribution of S) and ^{204}Tl (localization of the cathodes).

Apparatus for corrosion tests with hot municipal waters R. M. Guest (*J. Am. Water Works Assoc.*, 1960, **52,** Sept., 1142–1144) A tank simulating service conditions is described. The composition of the water and not that of the steel was found to be important.

Autoclave testing of type 304 stainless steel L. E. Phillips (*MND–E*–1322, *PB* 151149, 1958, May, pp.61; from *US Res. Rep.*, 1959, **31,** May 15, 354) U-bend test specimens were tested in corrosive water in rocker autoclaves; O_2 and Cl^- were the only variables which contributed to cracking, and the levels of each which produced cracking were determined. In the presence of Cl^-, oxide film formation can induce stress corrosion cracking even if the O_2 concentration of the environment is low.

Accelerated corrosion tests of electrodeposited tin coatings on steels T. Biestek (*Prace Inst. Mech.*, 1958, **6,** (23), 64–72) After an examination of information available in the literature,

the author deals with his experimental results on a tin coating subjected to accelerated corrosion. On this basis, the following conclusions were drawn after applying the following tests; corrosion in artificial industrial atmosphere, with 3% salt spray, with spray containing different salts, in hot water, and in 10%NH_4Cl solution. There was a relation between the thickness of the coating and the corrosion resistance; mechanical polishing decreases corrosion resistance while passivation causes an increase; and the results show a correlation between natural and accelerated results to be possible.

The causes of corrosion between Silumin and cast iron in cooling water G. Schikorr (*Z. Metallk.*, 1960, **51**, Oct., 590–595) In motor cars the engine block is made of cast iron whereas in many cases the cylinder head is of Silumin, and Al–Si alloy with about 9%Al. Although this combination is usually highly satisfactory with respect to corrosion, severe corrosion has been observed in some instances. The author studied the corrosion behaviour of couples of cast iron with Silumin. Silumin is, in water, nobler than cast iron at room temp. and in the absence of oxygen in the water. At higher temp., and at room temp. in the presence of oxygen, the cast iron is the nobler metal. Corrosion in practice is mainly a function of the oxygen available, as the O_2 is consumed during the reaction.—T.G.

The corrosion behaviour of iron–carbon alloys with up to 4%C in aqueous solutions P. Speidel and A. Wittmoser (*Giesserei Techn.-Wiss. Beih.*, 1960, July, 1607–1615) The behaviour of iron and steel was investigated in mains water, synthetic sea water, and brine with or without the application of an electric current. The behaviour of steel and cast iron, and of lamellar graphitic, nodular, and malleable cast iron is compared (30 refs).

The corrosion-resistance of zinc deposits on steel, iron and cast iron that has not been cleaned properly W. Demnitz (*Metalloberfläche*, 1960, **14**, Nov., 345–350) Zinc deposits were obtained by flame-spraying on steel, iron, and cast iron that was deliberately not cleaned properly. Deposits sprayed with the electric arc pistol were superior to all others and showed as good a corrosion-resistance as deposits on metallically clean surfaces. In no case did the deposits flake off during a test period of seven years. The results show that protection by flame-sprayed zinc films is even then efficient when cleaning of the surface is either not possible or too expensive. The tests were conducted in the air and in electrolyte solutions. T.G.

Results of static corrosion tests on various nickel base brazing alloys used to fabricate 304 stainless steel T-joints. Joints tested in sodium and fluoride (NaF–ZrF_4–UF_4) for 100 hours at 1500°F E. E. Hoffman (*CF*–54–12–26, 1954, Dec., pp.3; from *Nucl. Sci. Abs.*, 1959, **13**, Dec. 31, 2996) The results of corrosion tests on Ni-base brazing alloys indicated that all the alloys tested had good resistance to attack by fused chlorides. The Cr–Ni–P system showed good resistance to attack by both fused fluoride and sodium.

The corrosion of mild steel by combustion gases T. K. Ross, A. J. Macnab, and B. E. Leyland (*J. Inst. Fuel*, 1960, **33**, 540–542) The short-term corrosion of mild steel by SO_2 in reducing atm. above the dew-point is considered and the differences in degree of attack are compared with those found in the presence of O_2. The quantitative effects of temp. and conc. are such that in both cases scaling varies with $[SO_2]^{\frac{1}{2}}$. With SO_2+N_2, scaling proceeds approximately as the third power of the temp. but the presence of H_2 increases this to $\sim$ the fifth power (14 refs).—C.V.

Corrosion of austenitic piping by a sea water–air atmosphere M. J. McGoff (*MSAR*–59–112; *Tech. Rep.* 66, 1959, Oct., pp.12; from *Nucl. Sci. Abs.*, 1960, **14**, Jan. 15, 80) Stressed type 304 stainless steel pipe specimens were exposed to a high humidity sea water–air environment for a 1000-h period to investigate the occurrence of chloride stress corrosion. Constant temp. specimens were held at 550, 400, 200, and 125°F and cyclic specimens were varied from 550 to 125°F in a compartment where the ambient temp. was 125°F. Chloride stress corrosion occurred with specimens whose temp. was 125°F whereas higher temp. specimens and those which were thermally cycled from 125 to 550 to 125°F every 24 h did not show corrosion.—R.S.F.C.

Corrosion of D loop H. K. Lembersky and P. Cohen (*WAPD–CP*–715, (*Del*), 1957, Nov., pp.15; from *Nucl. Sci. Abs.*, 1960, **14**, Jan. 15, 80–81) The effect of ageing on the rate of corrosion in D loop, a large type 347 stainless steel circulating water system, was determined. The study of the possible effect of high water purity on the corrosion rate was a secondary objective of the investigation. The loop was operated for approximately 700 h with degassed system water at 1700 psi 490°F and a flow of 3200 to 4000 gpm. Corrosion rate was determined by H_2 evolution.—R.S.F.C.

Measurement of thickness and porosity of oxide films on iron and aluminium K. F. Lorking (*J. Appl. Chem.*, 1960, **10**, Nov., 449–456) These have been determined by an ac bridge. Where the oxide film is coherent and impermeable to the passage of cations, the capacity across the oxide covered surface is low and rises in a linear fashion as the film thickness decreases; capacity values at 2000 c/s may be used for the determination of film thickness. Where the oxide has been rendered porous, capacity results are high at low frequencies but fall as the frequency increases. Capacity values cannot be used for the determination of the thickness of these. The resistance is low, except where H_2 is evolved slowly from the surface. The potential falls to that of the oxide-free metal. Capacity measurement on Al freshly immersed in solutions inhibiting corrosion show the thickness of the oxide film (suitably treated) to be 10Å; similar measurements on Fe give a measurement of the film at 52Å. This film on Al is more readily kept in repair than with Fe and the changes that take place can be followed. This cannot be done with Fe in a neutral corrosive solution as the film is porous. The increase in permeability of the film with Al due to the Cl ions is detected by potential measurements and not by capacity.

New theory of rust formation (*Corros. Prev.*, 1960, **7**, Nov., 43) Pure Fe-wire was reacted at 835°F with O_2 and H_2O vapour and the resulting minute scale corrosion was studied by electron microscope ($\times$300000). With dry O_2 the Fe forms a protective oxide coating; this grows into an infinite number of minute oxide whiskers. With moisture, iron oxide platelets spread across the metal surface; the RH was 3%.—C.V.

Reactions of iron and iron compounds with hydrogen and hydrogen sulphide W. Kawa, R. W. Hiteshue, R. B. Anderson, and H. Greenfield (*US Bur. Mines, Rep. Invest.*, 1960, (5690), pp.16) Fe (chemically pure, powder, H_2 reduced), Fe_3O_4 superconcentrate, Fe_2O_3 anhydrous, $FeSO_4$, $7H_2O$ analytical reagent, Fe oxalate purified powder, $FeCl_2$, $4H_2O$ chemically pure, $FeCl_3$, $6H_2O$ lumps analytical reagent, and halogen-free H_2D were used. Two forms of H_2 were employed; electrolytic containing $<0{\cdot}2\%O_2$, this being removed before use, and that from steam and CH_4 containing no O_2. All the Fe compounds reacted as rapidly with H_2S at 2 atm. as they did with H_2 at high pressure. For reducing Fe_2O_3 or $FeSO_4$, H_2+H_2S were more effective than either alone. In autoclave experiments with coal in which H_2S is added to the charge, appreciable FeS will be formed from Fe, Fe_3O_4, Fe_2O_3 and Fe oxalate by the time 400° is reached; the formation of FeS at this temp. even without the addition of H_2S is discussed. Similar conclusions may be drawn with $FeSO_4$. $FeCl_3$ is readily reduced by H_2 at 200° but $FeCl_2$ is stable in H_2 at 500°. Sulphiding of these Fe salts presumably occurs at the surface and progresses inward and their capacity to act as heterogeneous catalysts in hydrogenation is discussed.—C.V.

Change of cell dimension in oxidation of iozite into magnetite and maghemite E. P. Sal'dau (**Zapiski Vsesoyuznogo Mineralogicheskogo Obshchestva*, 1957, **86**, (3), 324–335).

Corrosion tests and the interpretation of results E. A. Ollard (*Corros. Prev.*, 1960, **7**, Sept., 37–39, 58) A paper outlining the variations of conditions and purposes of performance tests, the special difficulties presented by plated metals, with a discussion of the movement to produce specifications for the commoner deposits and the need for standard assessment tests, closing with a suggested method for training inspectors.—S.H.-S.

Thermal history from corrosion product P. K. Foster (*JISI*, 1961, **199**, Sept., 18–21) [This issue].

A comparison of the corrosiveness of indoor atmospheres J. F. Stanners (*J. Appl. Chem.*, 1960, **10**, Nov., 461–470) Bare low-alloy and mild steels sprayed with Al or Zn were exposed to 45 different indoor atm., domestic and those of chemical factories being mostly used. Those in which large quantities of acid were used were the most corrosive, several being more corrosive than outdoors at Sheffield; this was particularly true of the coated metals. Although Al protected the steel better than Zn when freely exposed outdoors in an industrial atm. a Zn coating coating was much superior to Al in many of the indoor atm. High humidity increased corrosion rate.—C.V.

The corrosion of malleable iron in liquid corrosive N. Tsutsumi (*Waseda Univ., Rep. Casting Res. Lab.*, 1959, Dec., 37–51) The reduction of tensile strength of malleable iron compared with that of steel and cast iron in various liquid corrosives were determined. Experiments showed that it was quite interesting to compare the tensile strength for section area before corrosion to that for section after corrosion, i.e. that the type of corrosion had a remarkable effect on the tensile strength. With our empirical knowledge about corrosion phenomena in actual conditions of use, results obtained showed no effective data proving that black-heart malleable iron without a skin has higher resistance to corrosion than mild steel or grey iron.—C.F.C.

Investigation on acid-resistant high-silicon iron H. Sawamura, O. Tajima, and K. Akamatsu (*Proc. 1st Japan Congress on Testing Materials*, 1958, 107–110) The effects of Si and C and of various alloying elements on the mechanical properties; corrosion resistance and shrinkage of acid-resistant, high-Si irons are investigated.

Evaluation of corrosion in diesel cylinders J. M. A. van der Horst and W. Schultze (*ASME*, 1959, *Paper No.59–OGP*–2, pp.8) A method of measuring corrosion and distinguishing it from abrasion on a 40-h run. Tests on marine lubricants and additives, including NH_3, showed considerable degrees of protection.

The corrosion resistance of cast nickel–molybdenum–iron alloys G. N. Flint (*Metallurgia*, 1960, **62**, Nov., 195–200) Test results are reported showing the effect of composition and heat-treatment on the hardness and resistance to corrosion by strongly acid media of Mo–Ni–Fe alloys. It is shown that for most applications an alloy containing 26–30%Mo, 4–7%Fe, the balance being mainly Ni, has optimum corrosion resistance and economy of production. For applications requiring resistance to abrasion and corrosion, an alloy with 30%Mo and $<1\%$Fe is recommended; it has much greater hardness and better corrosion resistance when aged.

Caustic stress corrosion—tests on stainless steel E. Howells (*Corros. Techn.*, 1960, **7**, Nov.' 368–369) Three series of tests are described on type 175 stainless steel, carried out at the Knolls atomic power laboratory by General Electric Co. and at Babcock & Wilcox's Ltd's research centre at Alliance, Ohio. The first series examined the effect of NaOH concentration in water and Na, the second set studied the influence of stress levels, and the third series of tests was made in miniature boilers to study the effects of dilute NaOH solutions under heat transfer conditions. The results are reported.

On the transpassivity of the austenitic 18/8 stainless steels and their carbon content I. Epelboin, M. Froment, and P. Morel (*Corros. et Anticorros.*, 1960, **8**, Nov., 383–393) The phenomenon known as secondary passivity is studied by two simultaneous methods: making the potentiostat tracing of the characteristic current-emf while observing the state of the

surface of the electrode in the course of the electrolysis. The speed of dissolution of the anode and the condition of its surface depend closely on the potential of the electrode and the current-emf curves show that the existence and importance of secondary passivity depend on the carbon content.—S.H.-S.

On oxide films and scales of the Fe–Si–Cr system alloys at high temperature M. Sugiyama and T. Nakayama (*Nippon Kinzoku*, 1960, **24**, (6), 370–374) The scales were mainly of Cr_2O_3 or α (Cr, Fe)$_2$O$_3$ at 700–1 000°. SiO_2 was not observed. The heat-resistant films formed in air in 7 h at 1100–1 200°C consist of Cr_2O_3.

Growth and adhesion of oxide in furnace deposits J. Steel (*Nature*, 1960, **188**, Dec. 31, 1187) A letter. Growth of acicular or plate-like forms on 5%Cr–0·5%Mo steel has been observed in the electron microscope. Growth is fast where the fuel contains a metallic salt.

The nature of the oxide film formed on stainless steel immersed in concentrated hydrogen peroxide (H.T.P.) J. Diederichsen (*J. Appl. Chem.*, 1960, **10**, Dec., 497–505) Stainless steel (BS.970 En58B) and mild steel (En2A) were immersed in HTP. With stainless, a film is produced on the steel; this consists mainly of Fe oxides and it grows to a final thickness of $\sim 3\times10^{-6}$in. in 3–4 weeks During this growth the Cr dissolves in the peroxide at a decreasing rate and it is shown that the oxide film is relatively compatible with the HTP and that the decomposition of the peroxide is chiefly due to the Cr which has passed into solution. It is concluded that the compatibility of stainless is improved when it is shown that a film is stable in air and water for about 1 week and it is shown that a film of similar thickness cannot be produced with HNO_3.—C.V.

The equilibria between sulphur in molten iron and gaseous sulphur and sulphur dioxide A. Adachi and Z. Morita (*Osaka Univ. Fac. Eng. Techn. Rep.*, 1960, **10**, Oct., 789–796); also in *Tetsu-to-Hagane*, 1961, **47**, Jan., 16–21) [In Japanese] The equilibrium relations between dissolved S in molten iron and gaseous sulphur, and SO_2 were established by means of some thermodynamic calculations. From these relations, the pressures of sulphur vapour and SO_2 in equilibrium with molten iron as well as the heats of vaporization of S from the bath were determined. It was also proved that S would behave in the atomic state in the gas phase in the case of a bath containing small amounts of S at high temp. such as in steelmaking practice.—C.F.C.

Studies on the compatibility of high-temperature carbon dioxide with stainless steels and other materials General Nuclear Engineering Corp. (*GNEC*–121, 1959, Dec., pp.29; from *Nucl. Sci. Abs.*, 1960, **14**, Nov. 30, 3009) The compatibility of CO_2 with various stainless steels, Al–Cr–Fe alloys, Cr-steel, carbon steel, and Ni alloys was studied at 1 050 to 1 500°F. The effects of temp., pressure, gas velocity, solution annealing, and water vapour in the CO_2 on the corrosion rates of the above alloys and stainless steels were studied.—C.F.C.

Influence of pressure on the oxidation of iron and some steels by CO_2 M. Colombié (*Compt. Rend.*, 1960, **251**, Dec. 19, 2938–2940) After systematic tests conducted at 525°C, it was proved that partial pressure of CO_2 between 1 and 16 kg/cm² increased the speed of oxidation of iron, carbon steels, and a steel with 3%Cr.

New corrosion-testing service solves pipe-valve problems Alloy Steel Products Co. (*Iron Age*, 1960, **186**, Dec. 22, 64–65) A new testing service, whereby a special testing rod mounted inside the desired processing line has samples of many different alloys attached to it and exposed to the corrosive solution for at least 60 days, is described and some test results presented and discussed.—S.H.-S.

Relative corrodibility of zinc and steel in unpolluted atmospheres K. S. Rajagopalan and G. Ramaseshan (*J. Appl. Chem.*, 1960, **10**, Dec., 493–496) Mild steel (0·1%C, 0·028%S, 0·07%P, 0·46%Mn, 0·07%Si) and Zn (99·5% Zn, 0·46%Pb, 0·03%Fe) were used and the preparation of the specimens and humidifying solutions is described. Distribution of rust on the steel was completely random and the pattern did not differ markedly over the 30, 60, and 120 days test, except at 95 and 100% R.H. at 40°. The position with Zn is quite different, the extent of corrosion increasing from 2·3 mg/dm² at 35° and 65% R.H. in 30 days to 40 mg/dm² at 100% R.H. and values up to 1200 mg/dm² are noted.—C.V.

Extended field testing of stainless wire R. E. Paret (*Wire Wire Prod.*, 1960, **35**, April, 475, 477, 522) A valve with 20 years' service at a dam on the Mississippi is described.

Standardizing the preparation of electrodeposits on test panels for corrosion testing A. K. Graham and H. L. Pinkerton (*Proc. ASTM*, 1959, **59**, 317–329) In the past, although test programmes have been carefully carried out, preparations have not been so carefully made, or at least reported. The prepreparation of specimens for an ASTM investigation is given in detail. Base metal selection and inspection, preparation for plating, plating of test specimens, standardization of buffing losses, controls, and their calibration are discussed (22 refs).

Preliminary data on 1958 atmospheric exposure of hardware specimens (*Proc. ASTM*, 1959, **59**, 133–155) The results described are for tests of the effectiveness of hot-dipped zinc, hot-dipped Al, electroplated and sprayed zinc, and sprayed Al coatings on carbon steel, low-alloy steels, nodular, and malleable irons. The test procedures, and preparation of the specimens are very fully described.

The proceedings of the commission for the study of corrosion and marine fouling of the European Organization for Economic Cooperation (*Peint. Pig. Ver.*, 1960, **36**, Nov., 631–633) Minutes of the proceedings are given.

Monitoring corrosion in the production of coal chemicals R. J. Schmitt and R. R. Christian (*Ind. Eng. Chem.*, 1960, **52**, Nov., 57A–59) The use of an electrical resistance probe is described and the advantages compared with wt-loss and microscopical metallographic methods. The employment of this in tar-distillation plants, ore-handling, and in the foul-gas line, is described but examples are also given which show its limitations. In a sinter plant, probe readings were inconsistent as the temp. element could not be readily adjusted to the fluctuating exhaust-gas temp.; in a plant where H_2S was being removed from refined benzene-toluene-xylene, Fe-sulphide corrosion deposit formed on the probe element and where non-uniform corrosion is found, this method is unsatisfactory. In summary, it is considered that with sufficient experience this can be a very useful tool in plant corrosion studies or/and it can be a useful complement to weight-loss specimen testing.

Effects of moisture on corrosion in petrochemical environments G. P. Gladis (*Chem. Eng. Prog.*, 1960, **56**, Oct., 43–46) Small amounts of water, often overlooked, can transform relatively innocuous dry halogenated chemicals into aggressive corrosives, causing considerable equipment deterioration and product contamination. Corrosion test data for common materials of construction are presented, covering chlorocarbons, chlorinated hydrocarbons, and CCl_4, Distillation and rectification of crude CCl_4 and steam distillation and rectification of crude trichloroethylene are dealt with, and results are discussed.—S.H.-S.

Galvanic corrosion of titanium coupled with stainless steel Z. Takao, K. Nakano, and A. Takamura (*Nippon Kinzoku*, 1960, **24**, (6), 380–383) Reducing acids move the passive zone to Ti with reduction in corrosion rate. In oxidizing acids both metals were passive. Chloride solutions were irregular in potential distribution but corrosion was negligible.

Effect of long-time heating on the tendency of 1Kh18N9T steel to intercrystalline corrosion Kh. I. Cheskis, S. I. Vol'fson, and Yu. S. Medvedev (*Mezhkristallitnaya korroziya i korroziya metallov v napryazhennom sostoyanii*, 1960, Moscow, 27–44) Heating for 2 h at 650° does not increase the tendency to corrosion, but this tendency is increased on heating at 500–650°. Introduction of Ti has a similar effect. Long-term heating for up to 5000 h at 550 and 650° is recommended. **Study of the tendency to intercrystalline corrosion of chromium–nickel steels types 0Kh18N9, 1Kh18N9, and 1Kh18N9T** F. F. Khimushin and Z. F. Istrina (45–58) Tests were carried out on steel 1Kh18N9T, and on steels 0Kh18N9 and 1Kh18N9. Tests were made in a boiling solution of H_2SO_4 and $CuSO_4$ and by anode etching. Effect of heat-treatment on corrosion resistance in HNO_3 was also studied. **Concentrated intercrystalline corrosion along the fusion line in welded joints of stabilized steels type 18–8 (knife-edge corrosion)** B. I. Medovar, N. A. Langer, and M. M. Kurtepov (59–70) The main cause of knife-edge corrosion is the fusion of carbides of Ti or Nb+Ta in austenite as a result of heating the parent metal above 1 300° and the subsequent precipitation of Cr carbides along the austenite grain boundaries (23 refs). **Effect of electric heating of steel 1Kh18N9T on the processes determining its resistance to intercrystalline corrosion** V. V. Levitin and L. V. Mironov (71–78) Behaviour of the carbide phase was studied during high-speed induction annealing (450°/s). This was compared with heating in a salt bath. The scheme is also given of the disintegration of austenite supersaturated with carbon. **Effect of heat-treatment on the tendency of certain stainless steels to intercrystalline corrosion** E. A. Davidovskaya, L. P. Kestel', and E. I. Uryupina (79–91) A number of steels was investigated. Factors considered included quenching and subsequent annealing, tempering, stabilizing, tempering, and long-time ageing at different temp. and for different periods. **Intercrystalline corrosion of austenitic steels of increased strength in sea water** N. P. Talov (92–105) It is shown that the cause of the appearance of the tendency of steel to intercrystalline corrosion is not linked with the union of grain boundaries with Cr, and is caused only by the separation of carbides along the grain boundaries and is independent of their composition. If the preferential preparation of excess phases (carbides) along the grain boundaries is removed, the tendency to corrosion disappears. **Intercrystalline corrosion and corrosive cracking of high-alloy austenitic stainless steels** G. L. Shvarts and Yu. S. Kuznetsova (110–125) For various heats of steels Kh23N27M2T, Kh23N28M3D3T, and Kh23N23M3D3 critical temp. regions have been determined and also the minimum holding time at these temp. which induce a tendency of the steels to intercrystalline corrosion. **Concerning the tendency of chromium–nickel–molybdenum copper steels to intercrystalline corrosion** E. V. Zotova (126–144) Steels of this kind, which, after quenching, have an austenitic structure are inclined to intercrystalline corrosion after holding at 600–800°. There is no such tendency in steels with an austenitic-ferritic structure. With an austenitic–martensitic structure overall corrosion is observed. **Creation of two-phase steels: effective method of increasing resistance of stainless steels to intercrystalline corrosion** A. A. Babakov (145–147) Three experimental steels were developed based on grade Kh21N5. They were highly resistant to intercrystalline corrosion and corrosion under stress. With an increase in Cr content the ferrite component in two-phase steels sets up a 'barrier' against corrosion. **Another contribution on the question of the causes of intercrystalline corrosion of stainless steels** I. A. Levin (148–151) Three main factors contribute to this corrosion: (a) carbides, (b) particles united by Cr, and (c) considerable mechanical stresses. Further work should be concerned with determining the effect of each of these factors according to given conditions. **Determination of intercrystalline corrosion of austenitic Cr–Ni steels by measuring internal friction** M. A. Vedeneev and N. D. Tomashov (152–161) Internal friction, frequency of natural oscillations (resonance frequency and frequency of free torsion oscillations) as well as electric resistance are quantitative characteristics of intercrystalline corrosion. **Rapid method of determining the tendency of stainless steels to intercrystalline corrosion** L. Ya. Gurvich and K. A. Khoshchevskaya (162–177) The proposed method of testing takes place in a solution containing 20%HNO_3 and 1%NaF at room temp. Time taken to test a 0·5–3·0 mm specimen is 2 h. Good results have been obtained. **Role of electrochemical factors in the process of corrosion cracking of austenitic steels** A. V. Ryabchenkov and V. M. Nikiforova (178–197) On the basis of macro- and micro-electrochemical

investigations it is shown that electrochemical factors play a large part in the appearance and development of the process of corrosion cracking of austenitic steels. **Effect of various media on the corrosion of austenitic steels under stress at above-critical parameters** D. Ya. Kagan and T. M. Mikhailova (198–209) Most steels used for steam superheaters and steam pipes are very sensitive to alkaline substances, the existence of which in water cannot be excluded. A high degree of steam purity is therefore necessary in order to remove salts from the turbine and to ensure reliable operation of the metal in the superheaters and pipes. **Resistance of steels for hydroturbine blades in cavitation destruction depending on homogeneity of the structure and mechanical properties** M. G. Timberulatov, I. P. Kryanin, and G. I. Babushkina (217–230) In addition to resistance to cavitation, the microstructure, mechanical and casting properties, weldability, etc., were studied of steels for large blades of rotating-turbine blades. Three types of steels are recommended. **Corrosion cracking of high-strength steels** F. F. Azhogin (231–250) Factors studied include corrosion under stress in a solution of acids, NaOH, and NH_4NO_3; effect of surface state on corrosion under stress (effect of sand-blasting, metal-shot blasting, and removal of surface layer); effect of tempering temp. and tempering bath composition; and kinetics of crack development. **Corrosion cracking of welded apparatus made from carbon steel in sodium nitrate solutions** M. M. Kristal' (251–256) Corrosion cracking was observed in welded joints, made from grade St3 steel, under static tensile stresses. Cracking took place in heat-affected zone and was intercrystalline. Grade 20 steel was not so subject to cracking. Low-temp. annealing had a beneficial effect. **Cracking of springs of safety valves in contact with unstable benzines and compressed gases** O. G. Fedotov, S. I. Vol'fson, Kh. I. Cheskis, and L. D. Zakharochkin (269–274) In 1954–5 oil refineries, particularly those working with sulphurous oil, reported the cracking of safety valve springs made from steels 50KhGA and 6052. A protective cover was designed and tests of this cover, both in laboratories and at refineries, have yielded positive results.—A.I.P.

Metallurgical investigation of the stress corrosion failure in the stainless steel clad of the SIC reactor vessel G. Zuromsky (*CEND*–78, pp.21; from *Nucl. Sci. Abs.*, 1960, **14,** Oct. 31, 2651) An investigation of the extent and nature of the stress corrosion failure in the stainless steel cladding of the SIC reactor vessel is described The stress corrosion failure is attributed to the combined residual tensile stresses in the stainless steel clad resulting from 'omega' seal welding and corrosive chemicals from decomposition of the 'Viton' O-ring.—C.F.C.

Study on stress corrosion cracking of austenitic stainless steels M. Watanabe and Y. Mukai (*Osaka Univ. Fac. Eng. Techn. Rep.*, 1960, **10,** March, 439–448) One of the most serious problems for chemical plants is that welded austenitic stainless steel has the tendency to cracking due to corrosion. In this paper the authors investigated the process of the initiation and propagation of the stress corrosion cracking of austenitic stainless steels in a boiling solution of 42%$MgCl_2$. The initiation time and propagation speed of crack at the several stress levels were determined by means of microscopical observation of the course of the stress-corrosion.—R.S.F.C.

Protection of metals. IV. Cathodic protection applied to the fight against corrosion in ships and other structures immersed in river and sea water. Experience with sheet steel test pieces M. Serra and J. J. Royuela (*Rev. Cien. Apl.*, 1960, **14,** 496–509) [In Spanish] Reports of a series of corrosion tests on steel plate are gives and the results are discussed. The cost of protection in the various Spanish ports is calculated and, in the general discussion following, it is concluded that the most economic protection of stationary parts is by means of impressed currents whereas anodes are more suitable for ships at sea (64 refs).—P.S.

Anodic protection C. Edeleanu and J. G. Gibson (*Chem. Ind.*, 1961, March, 301–308) After discussing the requirements for passivity, the practicability of anodic protection and its throwing power are presented and its effectiveness within limits is suggested, 'provided absolute safety is not demanded'.—S.H.-S.

Protection against corrosion by using mixed metal coatings followed by paint or varnish V. V. Marcu and P. Freund (*Rev. Mec. Appliq.*, 1960, **5,** (2), 283–293; from *Studii si Cercetari de Mec. Aplicata*, 1958, (9), 2) [In French] This article describes methods of corrosion protection of metals with Zn or Al coatings followed by paint which have proved entirely satisfactory and which are now applied on an industrial scale. Successful attempts have been made to use a steel coating to achieve economies.

Corrosion protection and surface treatment of hydraulic plants K. Strehle (*Met. Rein.+Vorbeh.*, 1961, **10,** March, 31–32) The development of a vinyl copolymer dispersion varnish is reported which fulfils the requirements of concrete protection in hydraulic installations, being chemically resistant to raw and treated water, resistant to bacterial attack, and adhering strongly to wet concrete. Also reported are the development of a sealing paste for smoothing the surface of the concrete, prior to plastic film application, and of epoxy-resin-based varnishes for submerged Fe pipes and frames.—M.L.

Cathodic protection of buried pipelines R. de Brouwer (*Centre Belge d'Etude et de Documentation des Eaux*, 1958, (94), 289–290) A brief review of the principles and practice of the cathodic protection of buried pipelines.

Protection of mains against soil corrosion T. Sunnen (*Centre Belge d'Etude et de Documentation des Eaux*, 1958, (94), Oct., 280–382) Various methods of treating iron and steel gas and water mains to be buried are discussed, including the treatment of joints but omitting cathodic protection.

Deep ground bed for casing cathodic protection J. P. Daly (*J. Petroleum Techn.*, 1961, **13,** Jan., 16–18) What is claimed at the first attempt with a deep (1000 ft) ground bed to protect casings cathodically in the corrosive zone is described, with early and incomplete data indicating favourable results. Actual corrosion protection, however, is not yet determined.—S.H.-S.

ANALYSIS

Methods for the analysis of gases in metallurgy H. Bindernagel (*Technik*, 1961, **16,** (1), 28–33) The Orsat gas analysis is described and discussed, mentioning especially the various errors which may occur and their causes. New methods of gas analysis, which are employed in metallurgy, are briefly discussed, covering gas interferometry, gas chromatography, and radiofrequency mass-spectrometry (13 refs).

The determination of oxygen and hydrogen in steel, using carrier gas techniques G. E. A. Shanahan (*Rev. Mét.*, 1961, **58,** Jan., 55–64) O_2 is converted to CO by melting in a C crucible, CO is extracted in a current of inert gas, oxidized to CO_2 and determined gravimetrically. Free H_2 is oxidized by heated CuO and Fe_2O_3, the water formed absorbed in methanol and titrated by Karl Fisher reagent.

Considerations of the gas contents in dissolved and combined form in iron carbon cast alloys A. Königer and M. Odendahl (*Giesserei Techn. Wiss. Beih.*, 1960, (28), April, 1545–1555) A new sampling device for the analysis of grey cast iron by vacuum fusion is described, and the effect of various treatments on the O_2 and H_2 content is examined and discussed. The theory of equilibrium in the unstable system Fe–C–Si–O is examined, and the influence of oxide nuclei on the crystallization of high-C iron investigated (52 refs).

Determination of oxygen in a sample taken from the melt M. Kaše and M. Mandl (*Hutn. Listy*, 1961, **16,** (1), 56–59) [In Czech] A vacuum extraction method developed in the Met. Res. Inst. in Prague, is described. One analysis may be carried out in 6–7 min, or in about twice this time if sample preparation and evaluation of results are also allowed for.—P.F.

Determination of ferrous oxide and ferric oxide in the presence of bivalent and quadrivalent manganese oxide S. Watanabe (*Nippon Kinzoku*, 1960, **24,** July, 401–405) [In Japanese] A method of solution in phosphoric/sulphurous acids and titration with metavanadate using diphenylamine to give ferrous iron is described.

Rapid determination of phosphorus and silicon in carbon steels E. Kalmár (*Koh. Lapok*, 1960, **93,** Aug., 373–378) A photometric method for rapid simultaneous determination of P and Si in a single sample of carbon steel is described in the paper.—P.K.

The co-precipitation of phosphate with lead molybdate in the British Standard Method for determining phosphorus in steel R. B. Heslop and R. Kirby (*Analyst*, 1961, **86,** Feb., 134–135) It has been reported that, using the BS method, co-precipitation of PO_4 with Pb-molybdate results in a high value (1:200) but experimental details were not given. A radiochemical study showed that this estimate is high, co-precipitation being actually less. The P content of steel in 25 determinations was 0·01–0·062% and there was a clear tendency towards greater precipitation of PO_4 as the P-content of the steel increased, but the highest value recorded amounted only to an increase of 0·32% in the wt of Pb molybdate.—C.V.

Rapid photometric determination of Al in carbon steel S. Wakamatsu (*Nippon Kinzoku*, 1960, **24,** (4), 233–237) [In Japanese] Full details are given of the method, which is based on reaction with Eriochrome cyanine-R to form a violet-red complex.—K.E.J.

Sodium peroxide sinter decomposition for the determination of silica in slags, refractories and iron ores W. E. Clarke (*BCIRA J.*, 1961, **9,** March, 185–188) Rafter's method of decomposing minerals by sintering with Na_2O_2 is studied and is applied to foundry slags, refractories, steelmaking slags, iron ores, sinters, sands, etc. The sample (0·5 g) is heated with 2 g reagent for 7–10 min in a Pt-crucible at $>500°$; the resulting sinter is extracted with H_2O, acidified, and silica determined by drying down with perchloric acid.—C.V.

Water of hydration in the system Fe–O T. G. O. Berg (*J. Am. Ceram. Soc.*, 1961, **44,** March, 131–135) Fe or $Fe+Fe_2O_3$ was heated in a stream of dried O_2; the amount of H_2O carried by the gas was determined as a function of time and temp. (300–1 100°F); H_2O was formed as the result of a reaction with the crucible and was absorbed by FeO, when present, and released when FeO was converted to Fe_3O_4. The apparent excess of O_2 or deficiency of Fe in FeO which has been reported is probably due to the presence of H_2O or hydroxide in the FeO. The other oxides appearing in the phase diagram with exact stoichiometry, absorbed or held much less water, if any (19 refs).—C.V.

Determining phosphorus in coal and coke: evaluation of volumetric colorimetric and gravimetric methods F. H. Gibson and W. H. Ode (*US Bur. Mines, Rep. Invest.* 5743, 1961, pp.21) It is concluded from the experimental data that the ASTM and British volumetric methods are equally suitable, although they differ in some details. Colorimetric methods based on Mo-blue, using either $SnCl_2$ or hydrazine HSO_4 as reducing agent give satisfactory results. The molybdivanadate colorimetric method is especially suitable when used in conjunction with procedures for complete analysis of ash. When only a limited number of analyses are to be made, the gravimetric method is probably the most convenient since no special apparatus or standard solutions are used and comparative determinations of P directly in the coal and in the ash showed that the whole of the P was recovered from the ash.—C.V.

INDUSTRIAL USES AND APPLICATIONS

Applications of stainless steels (*Usine Nouv.*, 1960, **17,** March 2, 33) [In French] The use of 18/8 stainless steel screws and bolts in the construction of a new dam on the Meuse in Belgium is described. High corrosion resistance is particularly necessary and the type chosen was AISI 304 19%Cr, 10%Ni, 0·08% max C.

Steel for concrete and prestressed concrete-development and present position in East Germany B. Ansorge (*Technik*, 1960, **15,** Oct., 645–651) Steels developed for these purposes

in East Germany are enumerated, and their properties and treatment described.

Metals and alloys in shipbuilding P. K. Chakravarty (*TISCO*, 1961, **8**, Jan., 15–34) A general discussion. A table is included relating to some 12 materials used for propeller castings showing their chemical composition, mechanical properties, and reaction to the salt-water fatigue test (37 refs).—C.V.

Steel wheels and tyres C. F. Ryan and B. B. Hundy (*J. Inst. Locomotive Eng.*, 1960–61, **50**, (3), 304–363) A very detailed communication: Service problems are reviewed (wear, thermal effects, fatigue, brittle failure, and corrosion), design and manufacturing factors are considered (built-up *vs.* solid wheels), and comparison is made between cast and rolled steel wheels. Service factors (track, lubrication, braking, speed, vehicle design, climatic conditions) are reviewed. In a very full discussion many of the foregoing points are further examined (38 refs).—C.V.

Switch to stainless cuts coupling cost Snap-Tite Inc. (*Steel*, 1961, **148**, March 20, 110) Some economies resulting from simplified fabrication, due to replacement of lower priced steels by Armco 17–4 PH stainless steel, are presented.—S.H.-S.

Service behaviour of metals in transport: Automobile, rail, air and marine B. R. Nijhawan (*TISCO*, 1961, **8**, Jan., 1–14) The many problems encountered in transport applications are discussed, and service behaviour is considered in the light of the conditions.

Special steels for the synthetic materials industry (*Technica*, 1960, **9**, Nov. 4, 1451–1455) The selection, properties, and thermal treatment of special steels are discussed in relation to their use.—R.P.

Modern materials in the chemical industry and in the construction of apparatus R. Kieffer and K. Sedlatschek (*Österreichische Chemiker-Zeitung*, 1961, **61**, Aug., 219–227, preprint) The manufacture, properties, and metallurgical applications of Ti, Zr, Mo, W, Ta, Nb, and 18–8 steel are reviewed briefly (21 refs).

High strength bolting for structural steelwork H. Martin (*Austr. Mech. Eng.*, 1961, **48**, Jan. 5, 27–29; from *Weld. Met. Fabr.*) The fact that high strength bolts used in structural work have shown themselves to be superior to rivets is discussed. Present practice is to replace each rivet by a high-tensile bolt of the same nominal dia. It is suggested that possibly this may also be superior to site welding.

On high-strength bolts for connections in steel construction T. Mori and K. Kajiyama (*Sumi Met.*, 1960, **12**, April, 453–458) [In Japanese] (No summary].

Stainless steel for supersonic flight—the Bristol 188 (*Brit. Steel.*, 1960, **26**, Oct., 346–347, 351) Notes on the welded stainless steel construction used in this aircraft.

Use of special shapes for steel window frames (*Acier-Stahl-Steel*, 1961, **26**, March, 123–124) Examples of window-frame construction in buildings in Venice and Paris with details of special shapes of steel frames employed are presented and briefly discussed.—S.H.-S.

'Steels for reactor pressure circuits' (*JISI*, 1961, **199**, Sept., 1–5) [This issue].

The steel cross at Buenos Aires J. Negni (*Acier-Stahl-Steel*, 1961, **26**, March, 129–130) The gigantic steel cross erected in the Palermo quarter of Buenos Aires for the recent Religious Congress is illustrated and described with structural data.—S.H.-S.

The glass and stainless steel frontages of the Orly Air Station administrative building S. Pascaud (*Acier-Stahl-Steel*, 1961, **26**, March, 125–128) The structure, with photographs of its frontage and rear wing, and data of steel frame construction, and glass mountings, is briefly described.—S.H.-S.

Fe–Ni–Co alloy for Fernico-glass joints W. Babinski and J. Nowotarski (*Rudy i Met. Niezelazne*, 1960, **5**, (11), 464–469) The chemical composition of the alloy used was: 28·5–29·5%Ni, 16·5%Co, 0·07–0·12%Si, 0·25–0·50% Mn, less than 0·02%C, less than 0·005%S, less than 0·01%P+, and that of the glass used 70%SiO_2, 3·4%Al_2O_3, 20–21%B_2O_3, 4% Na_2O, 5%K_2O, 0·04%Fe_2O_3, softening point 650–660°C. Despite the same coefficient of thermal expansion of the glass and the alloy some of the joints have failed because of the inherent error of the method of estimation of this coefficient. A method to eliminate this error has been given.

Forum on 'Ball mills using steel vs. pebble mills H. L. Ames and J. M. Hemstock (*Can. Min. Met. Bull.*, 1961, **54**, Jan., 87–99) Major controversial issues relating to grinding and crushing are reivewed and tabulated data are presented with a brief description by L. R. Hann of the conversion and expansion of Renabie Mines Mill to semi-autogeneous grinding, followed by an open discussion.—S.H.-S.

HISTORICAL

Furnaces and other finds from the Roman site at Tokod, Hungary A. Schleicher (*Koh. Lapok*, 1960, **93**, Aug., 341–351) This paper contains the results of the examination of metals, slags, furnaces, and other metallurgical finds from the Roman site at Tokod, Hungary.

When old iron was an heirloom J. Slee (*Brit. Steel*, 1960, **26**, Oct., 358–359) An historical note on the more picturesque uses of iron.

Early origins and recent enlargements of the first Spanish steel works J. Serrano (*Met. Elct.*, 1961, **25**, Feb., 102–106) In honour of the approaching 60th anniversary of the founding of the 'Altos Hornos de Vizcaya', the author presents a short sketch of the Bilbao steelworks starting in old ironworks at Guriezo in the district of Castro Urdiales, and traces the growth of the industry to the present day, with a brief closing reference to the house of Krupp's co-operation in the erection of the modern oxygen steel plant.—S.H.-S.

When pig iron came from sows O. A. Goulden (*Efco J.*, 1960, **1**, Nov., 11–13) The history of the iron industry in the Weald from Roman times to about 1543 is traced, the industry dying out within the next 100 years. A brief account is given of the working of a bloomery at Tudely and it was shown that the cost of the charcoal and labour was barely covered by the value of the iron produced; production was about 1 t/year and the discarded slag contained 30% iron. The French introduced the indirect process with a continuously running furnace the iron being purposely melted and the slag and iron tapped off; the cast iron was reheated and hammered into wrought iron. The sows that had previously been rejected were now purposefully made at the furnace mouth, being cast in sand, and to cater for the greater quantity of iron now available in the furnace little rivulets were created from the sow to a number of smaller cavities which were called pigs. The last 29 furnaces ceased operating about 1664.—C.B.

An iron millionaire of the last century F. Collingwood (*Iron Steel*, 1961, **34**, March, 110) A brief history of James Kitson, first Baron Airedale, is given. The Kitson connexion with iron goes back to his father who was a great friend of George Stephenson. By 1912 the Airedale factory had expanded so much that it occupied 12 acres and employed 2000. James Kitson was an original member of the Iron and Steel Institute being its President in 1889–1891 and being awarded the Bessemer Gold Medal in 1903.—C.V.

The Sheffield thwitel R. A. Mott (*Edgar Allen News*, 1961, **40**, March, 64–65) The historical development of the iron industry in the North of England before 1400 AD is discussed. In Chaucer's reference, it is uncertain whether he was referring to the Hallamshire or Sussex Sheffield; the essential point is that this line must have been written ~1380 whereas the cutlery industry in the North is first mentioned only in 1500 or possibly 1450. Apart from this point, the history outlined in most informative as it points to the existence of iron bloomeries at Kirby Orblaws in 1259, to ironmaking in the Forest of Knaresborough in 1216 and various other centres during the 13th and later centuries.—C.V.

Henry Foxall: Distinguished early American foundryman M. Somerville (*Iron Worker*, 1960–61, **25**, Winter, 2–9) A description of his life and work (1758–1823).

Sven Rinman and cast iron E. H. Schulz (*Giesserei*, 1960, **47**, Sept. 8, 501–505) A biographical sketch.

100-year old cast iron water main (*Gjuteriet*, 1961, **51**, (1), 5–6) Chemical and spectrographic analysis, mechanical properties, and structure of a piece of cast iron main of British manufacture laid 100 years ago in Stockholm are described.

Invar pioneer M. Scholfield (*Iron Coal Trades Rev.*, 1961, **182**, Feb. 10, 303) A short commemorative note on the work of Charles Edouard Guillaume the discoverer of Invar and Elinvar. Invar alloys of iron contained 36–38%Ni the iron having a very low-C-content and after ageing bars remained of constant length despite variation in temp. Elinvar alloys contained Cr-inclusions giving elastic rigidity over an appreciable temp. range while Perminvar contained 30%Fe, 45%Ni, and 25%Co and was specially noteworthy for constant permeability at low magnetizing forces, a characteristic useful for constant conductance.—C.V.

ECONOMICS AND STATISTICS

The situation of the world iron ore market A. Kurek (*Neue Hütte*, 1961, **6**, Feb., 106–110; March, 167–172) [In German] Statistical.

300,000,000 tons a year (*Ingot*, 1960, Oct., 30–32) The present-day world output of basic steel was made possible some 80 years ago by the work of Sidney Gilchrist Thomas whose ancient furnace still stands. He succeeded in eliminating P by means of the basic lined converter. His work is briefly described.—C.V.

Present and future for our metallurgy J. B. De Nardo (*Tecn. Indust.*, 1961, **34**, Feb., 217–226) [In Spanish] The author discusses the economic and technical aspects of the metallurgical industry of the Argentine and considers its future development.—P.S.

Austrian steel: Development and prospects F. Sethur (*J. Industr. Economics*, 1960, **8**, June, 249–264) The technical leadership and the promotion and adoption of new techniques have contributed greatly to Austria's position today, but her isolated position opposite the ECSC and the sharply declining profit margin of the current recession may well affect her expansion programme and the scale of ouptut.

The significance of the iron and steel works 'Duna' in the Hungarian National Economy R. Mossóczy (*Koh. Lapok*, 1960, **93**, Nov., 498–504) The present state and production of the Hungarian Iron and Steel Works 'Duna', founded in 1950, are discussed in the paper. After full development of these works (10^6 t steel production), the output of plates and sheets will be more than 46% of the entire Hungarian rolling stock as compared to 25% in 1958.—P.K.

48,000,000 tons of [Japanese] crude steel estimated for 1970 (*Far East Iron Steel Rep.*, 1960, **69**, Oct., 5–6) [In English] On the basis of 1959 production figures, the 1970 estimate for Japan is increased by 10 m tons over the 1959 estimate. Greatest forecast increases are in tinplate, sheet, and silicon sheets.—K.E.J.

Annual rated output of [Japanese] crude steel 21 million metric tons (*Far East Iron Steel Rep.*, 1960, **67**, Aug., 4–5) [In English] Japanese production figures for iron and steel (by production method and type of product) are given for the period Jan.–June 1960. Figures are above those of the preceding period, particularly converter steel, which increased by 54%.—K.E.J.

Rational determination of stocks in an iron and steel company O. D. Brosch (*Bol. ABM*, 1961, **17**, Jan., 147–170) [In Portuguese] A mathematical treatment to determine the minimum safe economic stock levels is given.

MISCELLANEOUS

Complexes of ferrous iron with tannic acid J. D. Hem (*US Geological Survey Water-Supply Paper*, 1459-D, 1960, 75–94).—C.F.C.

Automatic control of various operations in the iron and steel industry A. B. Chelyustkin and B. A. Levitanskii (Jan., 1952, pp.8; trans. of *Banyaszati Lapok* (Hungary), 1950, **5**, Dec., 700–704; originally from *Promyshlennaya Energetika* (USSR), 1950, **7**, (3), from *US Tech. Trans.*, 1961, **5**, Jan. 13, 20) [No Abstract].

Some chemical relationships among sulphur species and dissolved ferrous iron J. D. Hem

(*US Geological Survey Water-Supply paper* 1459-C, 1960, 57–73).—C.F.C.

Metallurgical documentation from research to practice M. R. Hyslop (*J. Franklin Inst.*, 1960, **270,** July, 27–33) Curves are given to show the cost of conventional searching as compared to machine searching. In factual problems, conventional methods are to be preferred since a trained searcher can limit the field while the machine has to cover the entire subject matter; this is likewise true of the second group where a query having at least one generic aspect, well-defined, is dealt with, but in this case the cost of conventional searching has risen steeply, being greatly in excess of the machine. In the third group, where a less well-defined query is to be dealt with, machine cost rises steeply; even in this case, it lies well below conventional methods. Examples of this group relate to 'high-strength steel' and 'notch sensitivity' which both require further definition as these constitute real research problems. The principal reason the cost by machine is lower in these last two groups is that in group 1 the operator does only the brain work while in the second the pages must also be laboriously turned.

Oxygenation of ferrous iron W. Stumm and G. F. Lee (*Ind. Eng. Chem.*, 1961, **53,** Feb., 143–146) The solubility equilibria of five Fe^2 and five Fe^3 reactions in solution are tabulated and discussed; special attention is paid to the practical aspects, it being pointed out that oxidation is but one step in the process of deferrization. Flocculation and sedimentation may co-determine the overall Fe removal rate in surface waters and in Fe-removal plants but many co-existent constituents may accelerate or decelerate both the oxidation and flocculation reactions. The present data suggest that oxidation may be the controlling factor up to pH 7 but thereafter flocculation may be the slowest step and above 8 the diffusion of O_2, rather than the chemical reaction determines the oxidation rate. Organic matter may stabilize the Fe oxide and colloids may increase the Fe^3 solubility by complex formation, and various aspects of this are discussed and the use of an oxidation catalyst such as Cu^2 will increase the oxidation rate, the addition of 0·02 mg/l reduces the oxygenation rate to one-fifth (25 refs).—C.V.

Gyromagnetic ratios of Fe and Ni G. G. Scott (*Phys. Rev.*, 1960, **119,** July 1, 84—85).

Simulator solves problems in heat applications Selas Corp. (*Steel*, 1961, **148,** March 13, 126–127) The thermolog, an electronic simulator, duplicating variations in conductivity of the material under study, as its temp. changes, and its potential applications in the solution of problems, is briefly described.—S.H.-S.

Production of strange particles by 2·8-Bev protons in C, Fe, and Pb T. Bowen, J. Hardy jun., G. T. Reynolds, G. Tagliaferri, A. E. Werbrouck, and W. H. Moore (*Phys. Rev.*, 1960, **119,** Sept. 15, 2041–2050).

Chromium W. McInnis (*US Bur. Mines, Bull.*, 1960, (585), 183–197) A general review. The lack of economic processes for the recovery of Cr from low-grade deposits is a problem to be solved while the lack of ductility and resistance to impact at room temp. are major problems that require solution if Cr and Cr-base alloys are to be used as structural materials, especially for high temp. work where oxidation resistance and strength are of the utmost importance.—C.V.

Cobalt J. H. Bilbrey jun. (*US Bur. Mines, Bull.*, 1960, (585), 213–224) The present position is reviewed. The lack of new and expanded uses for Co, requiring large quantities, is noted. The inadequate knowledge concerning the properties of high-purity and commercial Co and of the function of this metal in Co-base alloys has acted as a retardant towards its fuller use while the metallurgical complexities of the low-grade quality also present difficulties.

Columbium W. R. Barton (*US Bur. Mines, Bull.*, 1960, (585), 225–233) Several million tons of Nb have been found in complex oxide materials and in Ti-ores and these will have to be utilized if the expected demand for use in high temp. environments materializes. Various substitutes (Mo or W-alloys, ceramics, or ceramic coatings and claddings upon less heat-resistant alloys or glass-reinforced plastics) are suggested. In vacuum tubes, Ta, Zr, Ti, or mischmetal are preferable to Nb.—C.V.

Manganese G. L. DeHuff (*US Bur. Mines, Bull.*, 1960, (585), 493–510) The position of the USA as regards Mn is discussed. There are very large deposits of low-grade Mn-material and substantial resources of secondary materials such as OH slags. The major problem, the utilization of these, persists. The possibility of Mn being used as an anti-knock additive is briefly discussed, while its use as a partial substitute for Ni in stainless steels, as a noise- and vibration-damping alloy has still to be fully explored.—C.V.

Molybdenum W. McInnis (*US Bur. Mines, Bull.*, 1960, (585), 537–547) One-third of the future (USA) supply is expected to be obtained as a by-product of Cu and therefore the Cu position is the determining factor. Additionally, the recovery of molybdenum is poor while the high m.p. and affinity of Mo for O_2 present further problems. The protection of Mo from oxidation by ceramic coatings, claddings, electroplating, metal-dip, and metal-spray coatings and the use of molydenite lubricants is discussed.—C.V.

Nickel J. H. Bilbrey jun. (*US Bur. Mines, Bull.*, 1960, (585), 549–563) Research has been devoted to Ni and Co extraction, the continuous electric smelting of low-grade Ni ores, electric smelting of Cuban sepentine and laterite, up-grading Co–Ni stockpiles by the roasting flotation process, electrolytic separation of Ni and Co, co-deposition of Sn–Ni plate from organic and mixed aqueous-organic solvents, conversion of Ni oxide to Ni and precise analytical procedures for Ni- and Co-bearing materials. The low Ni content and extreme dissemination throughout the ore together with the presence of several other metals as unidentified compounds or minerals present a special problem in the study of Cuban laterite and serpentine.—C.V.

Tungsten R. W. Holliday (*US Bur. Mines, Bull.*, 1960, (585), 903–917) The difficulties arising in fabrication due to high hot strength and room-temp. brittleness are discussed together with the techniques of powder metallurgy in the production of larger size ingots or intricate shapes. In discussing substitutes, Mo can to some extent be used in tool steels, Ti or other carbides and sintered Al_2O_3 may be used in some applications to replace W carbides while it is pointed out that the use of transistors in the place of vacuum tubes may reduce the need for W in electronics and the use of fluorescent tubes has greatly replaced the use of W in electric filaments in lighting. The W bearing minerals, their occurrence, beneficiation, and refining are briefly reviewed

Vanadium P. M. Busch (*US Bur. Mines, Bull.*, 1960, (585), 941–948) An increased use for V is envisaged as the result of over-supply of V_2O_5 as a by-product of U-production. The resistance of V to aerated salt water, HCl, and H_2SO_4 is specially mentioned, comparison being made with many stainless steels. Other applications considered are, the production of a weldable, formable, hot high strength sheet alloy for airframe service up to 1200°F, for fuel element cladding in which interdiffusion, hot strength and thermal conductivity are of importance and as a diffusion barrier between steel and Ti in the production of clads between these two metals. The occurrence, etc., is discussed.—C.V.

Zirconium F. W. Wessel (*US Bur. Mines, Bull.*, 1960, (585), 995–1002) The occurrence and distribution is discussed together with the production of the metal, and the uses are indicated. The Zr–Hf separation, the high fabrication losses, and the small-scale production all contribute to the high cost; the ratio of sponge to finished product is >6 to 1. The necessity for further knowledge of the physical metallurgy and chemistry, on methods of production and on the properties of the carbides, nitrides, borides, silicides, and other similar compounds is required.—C.V.

The rate of combustion of iron wire in oxygen at high pressure L. Kirschfield (*Arch. Eisenh.*, 1961, **32,** Jan., 57–62) Rates of combustion of iron wires of 1 and 2 mm dia. respectively were measured in still O_2 at 1–100 atm. pressure, and relationships between rate of combustion and pressure established.

Training for Durgapur M. O. Bury (*Sci. Eng.*, 1960, Nov.–Dec., 155–160) Under the technical co-operative scheme of the Colombo Plan, all Indian supervisory staff was to be trained in the UK. Some details of this are given.—C.V.

Accident prevention in the iron and steel industry and its economic repercussions J. Alvarez Muñiz (*Dyna*, 1961, **36,** March, 157–171) [In Spanish] The author describes the position with regard to safety in the world's iron and steel industry and explains the operations of the various organizations concerned with accident prevention. The human and economic aspects are stressed.—P.S.

BOOK NOTICES

ARMYTAGE, W. H. G. '*A Social History of Engineering*'. $8\frac{1}{2}\times5\frac{1}{2}$in, pp.378. Illustrated. 1961, London: Faber and Faber. (Price £2 2*s*.)

SIEMENS, G. '*History of the House of Siemens*'. Trans. A. F. Rodger and L. N. Hole. Vols.I and II. $9\times5\frac{1}{2}$in, pp.332, 326. 1957, Freiburg/Munich: Verlag Karl Alber.

Professor Armytage's book is both narrower and wider than its title suggests—narrower in that it consists largely of a record of technical progress unrelated to social effects, wider in that it includes metallurgy and kindred subjects. It shows a very wide reading and a considerable grasp of technical matter, but it is unfortunate that the sections on iron and steel are marred by an apparent misunderstanding of basic steelmaking, and by the repetition of well-known errors, such as Dud Dudley's claim, and the assumption that Pierre and Émile Martin were brothers, instead of son and father. The author's broader view, however, will be widely appreciated—that 'to see where we want to go, we should, from time to time, reflect on the manner of our coming so far'.

Herr Siemens' book is of quite a different nature. The history of the house of Siemens is that of electrical development and manufacture in Germany and a considerable part of the world, both east and west, since the middle of last century. Immensely detailed, but lucid and compelling, this history is a record of the activities, both technical and financial, of the Siemens family of which the author is a member. From the early telegraph experiments of Werner Siemens, through lighting and telephone developments on to large-scale power production, to railway signalling, radio, and electric furnaces, Herr Siemens writes firmly and smoothly, explaining the technical bases as accurately as the financial ones, and showing how both were connected in the tremendous advance of German commerce and industry in the last century. His translators have served him extremely well; the same is to be said for his German printers.

—J. P. SAVILLE.

BOICHENKO, M. C. '*Continuous Casting of Steel*'. [Trans. by L. Herdan and R. Sewell; ed. by by G. Fenton.] $8\frac{3}{4}\times5\frac{1}{2}$in, pp.xi+218. Illustrated. 1961, London: Butterworths. (Price £2 10*s*.)

KOROTKOV, K. P. *et al.* '*The Continuous Casting of Steel in Commercial Use*'. [Trans. by V. Alford; ed. by H. T. Protheroe.] $8\frac{1}{2}\times5\frac{1}{2}$in, pp.x+171. Illustrated. 1960, London: Pergamon Press. (Price £2 10*s*.)

These two works are translations from the Russian and it is indeed a pleasure to welcome the appearance in English of the first books on the continuous casting of steel which are not merely lengthy and uncritical surveys of the generally outdated patent literature.

Boichenko has reviewed the important papers which were available in 1957, when the book first appeared in Russian. The task of categorizing the miscellaneous information contained in 60 technical and scientific papers originating in Germany, Austria, North America, Great Britain, and the Soviet

Union into chapters dealing with design, operation, metallurgy, economics, and basic theory has been very well done. The author has provided continuity by commenting on these important aspects of the subject, and from his standing in the field of continuous casting, his views should be considered with the respect they always merit. Boichenko points out that successful continuous casting depends vitally on the solidification process in the mould, and that there is still no satisfactory explanation of the true physical nature of the mechanism of heat transfer in the early stages. He regards the early theoretical work of Roth and of Tikhonov and Shvidkovski as based on too many approximations. In the light of more recent experimental work, Boichenko suggests that these earlier theories need reappraisal. The reproduction of the line drawings and photographs most of which are taken from the original papers, is admirable.

The publishers of the second book, by Korotkov *et al.*, have expressed regret that in the interests of making the book available quickly, the quality of the reproduction falls short of their normal standards. To those interested in the basic design and operation of a typical commercial continuous casting plant for steel, no such apology is required. The authors have reported in great detail on the commercial machine which has operated for over five years at the Krasnoye Sormovo steelworks at Gor'ki. Every aspect of the design, construction, and operation of this two-strand machine producing 7in × 16½in slabs is discussed and illustrated. There is a wealth of information on mould design, plant control equipment, operational requirements, and economics as applied to this specific installation.

Much of the information given may not be entirely novel to those intimately concerned elsewhere with continuous casting. However, it occasions no surprise that, as in other fields, Russian success in continuous casting can manifestly be attributed to a sound scientific appreciation of the problems involved.

There are a number of minor errors. For example, in those sections concerned with heat flow in the mould there is frequent reference to the drop, rather than to the increase in water temperature, and there is some inconsistency between the data presented in Tables 5 and 6. Those who wish to acquaint themselves with the general background to the continuous casting of steel should read Boichenko, while those also interested in plant design and operation should follow with Korotkov. These books are complementary, and both greatly enhance the literature on this topical subject.

J. SAVAGE.

GATOS, H. C. (Editor). '*The Surface Chemistry of Metals and Solids*'. 9 × 6in, pp.xi + 526. Illustrated. 1960, New York, London: John Wiley & Sons Inc. (Price £5.)

This book represents the papers read at a symposium of the Corrosion and Electronics Divisions of the Electrochemical Society, held in October 1959.

It is essentially a semi-conductor book. The first section headed Chemistry and Physics of Surfaces contains contributions by Brattain, Farnsworth, and others. But its contents are to a large extent restricted to a very limited aspect of this subject, that relating to semi-conductor surfaces. The main exception is a short chapter on the electronic properties of metal surfaces by Juretschke. The second section is devoted to imperfections and surface behaviour. We have contributions from Cabrera on the role of dislocations in reactivity. This author is satisfied that dislocations have little to do with oxide nuclei. He still feels, however, that they play a positive but unproven role in the growth of a nearly uniform film. This short contribution is followed by one of the more interesting discussions in the book. In general, the level of discussion is uneven, and like so many recorded discussions at symposia of this type, not of great value. Samuels contributes a useful review on surface damage, in which the modern conception of Beilby's theory is discussed. This is followed by a description of surface damage on silicon and germanium by Buck, and the effect of imperfections on chemical dissolution by Gatos. Faust has a useful contribution to make on etching effects, the most original being the effect of etching germanium with molten indium. Section three is on the subject of contacts between semiconductors and electrolytes or metals. This contains rather surprisingly a chapter by Lacombe on the electrolytic etching of metals. This is a useful chapter for metallurgists but contains material with which most of them will be familiar. This is followed by a similar chapter on the etching of semi-conductors. The next sections of the book are devoted to surface reactions in liquid media and gaseous media. The latter contains two papers on the subject of oxidation of metals by Hauffe and Gwathmey. While such contributions as these are welcome to the reviewer in particular, it is difficult to see where they fit in to the subject under discussion.

This book is by no means a book on the surface chemistry of metals, as the title implies. It could be more correctly described as a book on the surface chemistry of semiconductors with some references to those metals necessary for their efficient working. In fact, this book represents a marriage between two parties, corrosion and electronics, which part of the time is not even a marriage of convenience. As far as the semiconductor specialist is concerned, he will get more out of this marriage than will the physical metallurgist, who is asked to pay £5 for a book which will give him very little that he cannot get elsewhere. The standard of the illustrations is high, but the text seems to have been reproduced directly from typescript and although the typist's part in this work has been acknowledged, the editor has not corrected all her mistakes. There is a particularly irritating confusion between charge and change.

—R. F. TYLECOTE.

HOGARTH, C. A., and BLITZ, J. (Editors). '*Techniques of Non-Destructive Testing*'. 8½ × 5½in, pp.vii + 216. Illustrated. 1960, London: Butterworths. (Price £2.)

In their foreword, the editors state that this book, based on a course of lectures given in 1959, arose as a result of suggestions that the course material would be useful in book form. A number of excellent books covering this field has, however, been published in the last two years, and this must inevitably detract from the usefulness of the present volume. The editors and publishers are to be complimented on the presentation. The text and illustrations are very clearly laid out. As 11 authors have contributed, certain variations in style are unavoidable, but these are not too obtrusive. One major criticism is that the bibliography at the end of each chapter varies from the voluminous to the non-existent. Subjects covered include the traditional techniques of N.D.T., i.e. radiology, ultrasonics, magnetic methods, eddy current methods, and penetrant methods. An interesting chapter, covering the thermal comparator developed at N.P.L., serves to bring forward work that is perhaps less widely known and applied that it may merit. The final chapter on the application of non-destructive testing in an inspection organization is probably the most valuable in the whole book. Considerable emphasis is laid on the need for adequate training and experience of inspectors. It is not always appreciated that, while tests of the type described elsewhere in the book can be carried out quite simply, assessment of results to obtain maximum value from them is a highly skilled science, in which experience plays a large part. In conclusion, this book must be regarded as a useful and reasonably-priced addition to the literature in this field.—B. O. SMITH.

PIRANI, M. (Editor). '*Elektrothermie*'. 2 Aufl. 9 × 6in, pp.xii + 451. Illustrated. 1960, Berlin: Springer-Verlag. (Price DM.61.50.)

PASCHKIS, V., and PERSSON, J. '*Industrial Electric Furnaces and Appliances*'. 2nd ed. 9 × 6in, xvi + 607. Illustrated. 1960, New York, London: Interscience Publishers Ltd. (Price £9.)

The German work edited by Professor Pirani, the first of these books, is an extremely well-produced volume which is a completely new edition of an earlier work. It covers most of the field of application of electrothermal processes to metallurgy and industrial chemistry. It is the co-ordinated work of a number of experts who have specialized in their respective subjects. The early chapters deal with the application of electric furnaces to iron- and steelmaking, and also to non-ferrous metallurgy, and they embrace arc, induction, and resistance furnaces. The section on non-ferrous metals even deals with the melting of the rarer metals, such as germanium and molybdenum, and the zone refining of silicon. There is, however, an important omission in so far as the electrothermal extraction of tin, nickel, and copper is not mentioned. Ensuing chapters deal with the manufacture of various carbides, graphite, cyanamide, and phosphorus, but there are also chapters covering ferrosilicon and calcium silicide. It is surprising, however, that the manufacture of ferromanganese and of ferro-chrome, which are just as important, are omitted. On the other hand, there are some excellent sections on the fusion of alumina, quartz, and glass; on dielectric heating, high temperature furnaces, and new laboratory techniques. The book is well illustrated and contains a copious bibliography—altogether a well-informed work.

The second book, a second and enlarged edition of an American publication, is of more interest to the furnace designer than to the furnace user. It deals very fully with the theoretical aspects, such as heat transfer, electrical theory, and characteristics. Some of these sections are very well done and include useful examples. Some readers might think the treatment of the subject is rather laboured, and there is some irritating verbiage such as heat losses being described as 'non-proportional independent'. Certain of the diagrams, although admittedly schematic, could have been more realistic, especially II–1, and II–7, while Fig.II–28 does not obviously depict a 1000-lb arc-furnace, but is of a unit many times that capacity. These criticisms, however, should not detract from the value of the work as a whole, which is a most comprehensive one, with the emphasis more on the theoretical than the practical side. On the whole the work is well-produced and adequately illustrated.

—A. G. D. ROBIETTE.

VEREIN DEUTSCHER EISENHÜTTENLEUTE. '*Chemische Gasanalyse*'. 8¼ × 5¾in, pp.v + 131. Illustrated. 1960, Düsseldorf: Verlag Stahleisen. (Price DM.9.80.)

In spite of recent major developments in gas analysis involving such techniques as gas chromatography, infra-red absorption, and thermal conductivity measurements, etc., the older and less glamorous chemical procedures will continue to be of the greatest importance in plant control for many years to come. In publishing this booklet, the V.D.Eh. has performed a useful service to the works chemist who is required, often at short notice, to sample and analyse gas mixtures.

After an introduction on the purpose of gas analysis, a very useful description is presented of gas sampling procedures. Due consideration is given to choice of probe position in the gas stream and this is followed by details of various pieces of apparatus designed to sample under different conditions. For example, apart from spot sampling methods, equipment is illustrated for continuous sampling at constant rate and also at rates proportional to the flow of gas in the main. Attention is next turned to the components of the Orsat gas analysis apparatus; detailed descriptions are given of measuring burettes, absorption pipettes, combustion pipettes and tubes, filters, etc., and the combinations best suited for the analysis of unburnt and waste gases. The

chemical aspects of gas analysis are discussed in great detail and include recommendations for displacement liquids in the burettes, and absorption solutions for carbon dioxide, various hydrocarbons, oxygen, and carbon monoxide. The combustion part of the analysis is treated fully including possible sources of error. A section is devoted to the actual manipulation of the Orsat, the readings taken, and the methods of calculation illustrated by examples. Finally the inferences of gas analysis are discussed and methods for calculating calorific values and controlling combustion explained.

The booklet is ideally suited to the practising works chemist. The diagrams are clear and descriptive and the calculations, with worked examples, are easily and quickly assimilated. A short index is provided.

—C. E. A. SHANAHAN.

ZUIDEMA, H. H. '*The Performance of Lubricating Oils*'. 2nd ed. A.C.S. Monograph No.143. 9 × 6in, pp.xi + 205. Illustrated. 1959, New York, London: Reinhold Publishing Corp., Chapman & Hall Ltd. (Price £2 16*s*.)

Publications in the American Chemical Society's series of Chemical Monographs are intended as complete and critical treatments of a relatively restricted area of knowledge in pure or applied chemistry. In addition to the discussion of available information the monographs include extensive references to the literature in their respective fields. The first edition of 'The Performance of Lubricating Oils' was published over eight years ago and rather than consider the various lubricating oils under headings according to application, the chapters were separated into discussions of the various performance characteristics. This form of presentation was preferred to a treatise on various oils according to their application which would need frequent revision in such a rapidly expanding field of technology. The second edition maintains the same presentation and incorporates in the text and bibliography much of the data on oil lubrication which has been published since the first edition. The discussion is based mainly on the study of lubricants for automobile equipment because most work appears to have been done in this field. The eight chapters cover the process of lubrication, rheology, oxidation, bearing corrosion, sludge, and lacquer deposition, emulsification, and foaming, wear, and manufacturing methods. Subjects new to this edition include multigrade motor oils, fretting wear, and paper chromatography. Intended for those concerned with the development, manufacture, and use of lubricating oils, it will obviously be of most use to the specialist in this field as a summary of present knowledge but as such the discussion of any particular subject is necessarily restricted. However, much of this book should be of interest to those not concerned with the chemical aspect of lubricating oils as this only predominates in the extensive chapter on oxidation and those dealing with bearing corrosion and manufacturing methods. Some of the standard tests for particular characteristics of lubricants are mentioned under the respective chapters but they are not considered to the extent which might be expected in a book of this nature.—P. L. LILLYWHITE.

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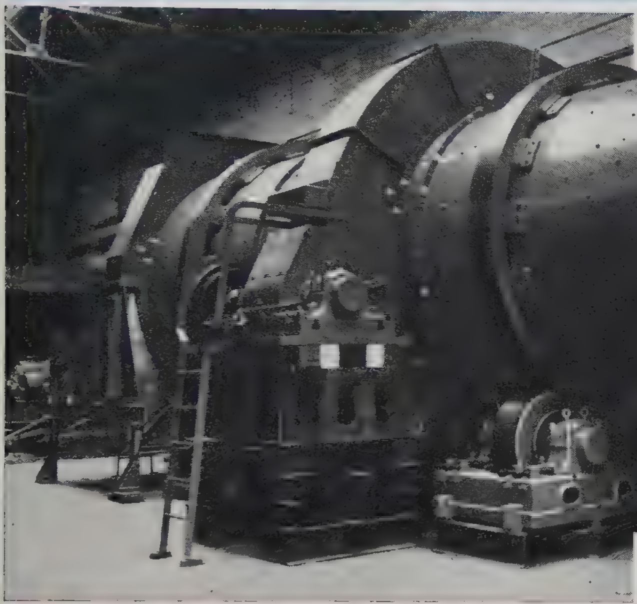

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This machine is now installed at the Works of Messrs. John Lysaght's Scunthorpe Works Limited, the main contractors being Messrs. Head Wrightson Iron and Steel Works Engineering Limited.

This machine as illustrated is designed for a capacity of 250 tons per hour.

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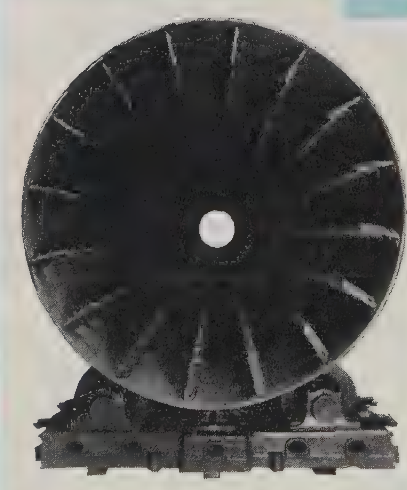

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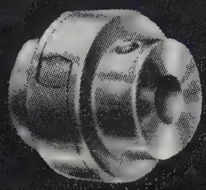

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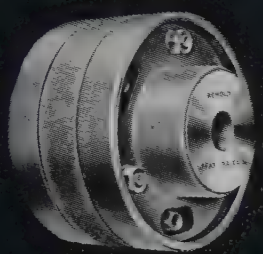

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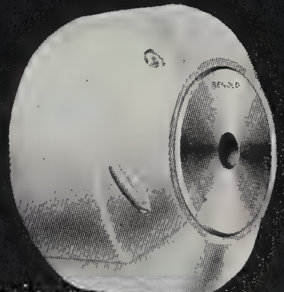

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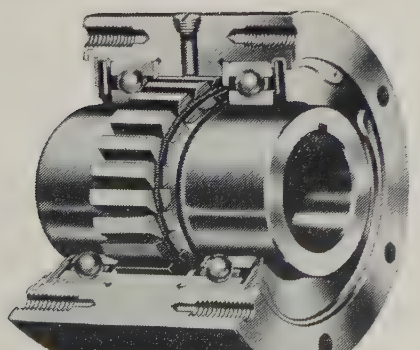

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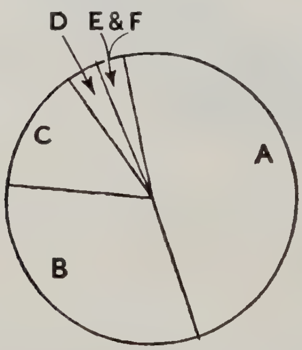
Factory Heating-1

The space heating of factories by electrical means can be achieved in a variety of ways which will be dealt with in the next Data Sheet.

Before deciding on any form of factory space heating—whether by means of electricity or not—it is as well to have clearly in mind all the components of the total annual running cost, and not merely the fuel cost, of the installation.

They are:

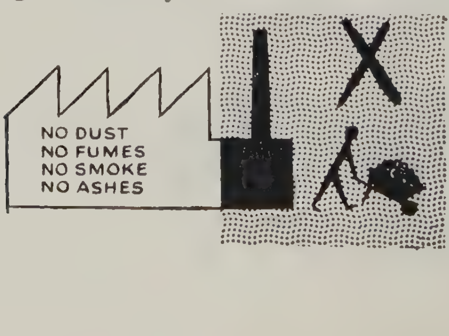
- (A) The cost of the fuel or the electricity,
- (B) Interest and depreciation on the capital cost of the installation,
- (C) Labour,
- (D) The cost of running auxiliary plant such as fans and pumps,
- (E) Maintenance,
- (F) Insurance.



In comparing fuel costs it should be borne in mind that electric heat is refined heat and has had all the fuss, bother and dirt of the conversion of fuel into heat taken out at the generating station.

In arriving at the true figures for capital cost and depreciation, maintenance, and insurance, those connected with such items as boilerhouse, chimney, fuel store and access road should be included; labour costs should include such tasks as ash disposal. None of these items occurs when electricity is used, although space will be required for the electric boiler and storage vessels in the case of the type (h) following.

Electricity provides the ideal answer to the requirements of the Clean Air Act, the impact of which has introduced an important new factor during the last few years.



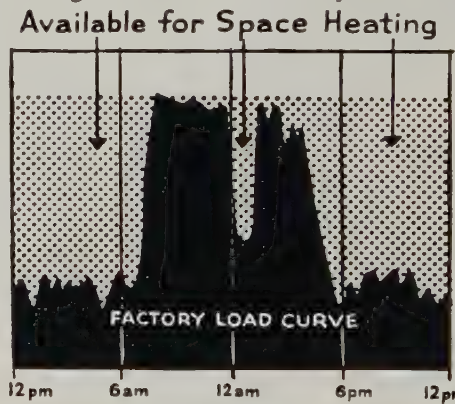
The following list gives the main types into which electric heating installations fall:

- (a) High temperature ("infra-red") overhead heaters operating at near red heat.
- (b) Medium temperature panels operating at surface temperatures of 400° to 600°F.
- (c) Extended surfaced heating in the shape of floorwarming operating at temperatures up to 80°F.
- (d) Oil and water filled radiators.
- (e) Tubular heaters.
- (f) Unit heaters.
- (g) Storage block heaters.
- (h) Electric boilers and water heaters operating in conjunction with hot water radiators or panels either with or without water storage.

All these methods of electric heating can be divided into two distinct classes:

- (a) Those that utilise electricity during "off-peak" hours and store the heat so generated for use at a later period.
- (b) Those that use electricity whenever the heating system is in use (i.e. direct electric heaters).

The use of a heat storage system in a small works on a block tariff takes advantage of the lower tariff offered for an off-peak supply, and in the larger factory on a Maximum Demand tariff means that the heating load will not incur any M.D. charge.



Alternatively there may be cases where the use of direct electric heaters can be integrated with other factory loads in such a way that they are not used during the factory peak periods and will thus incur no additional M.D. charge.

For further information, get in touch with your Electricity Board or write direct to the Electrical Development Association, 2 Savoy Hill, London, W.C.2.

Excellent reference books on the industrial and commercial uses of electricity and reprints of articles and papers are available. An example is "Higher Industrial Production with Electricity" (price 8/6 each or 9/- post free).

E.D.A. also have available on free loan in the U.K. a series of films on the industrial uses of electricity. Film and Book catalogues and Publications List sent on request.

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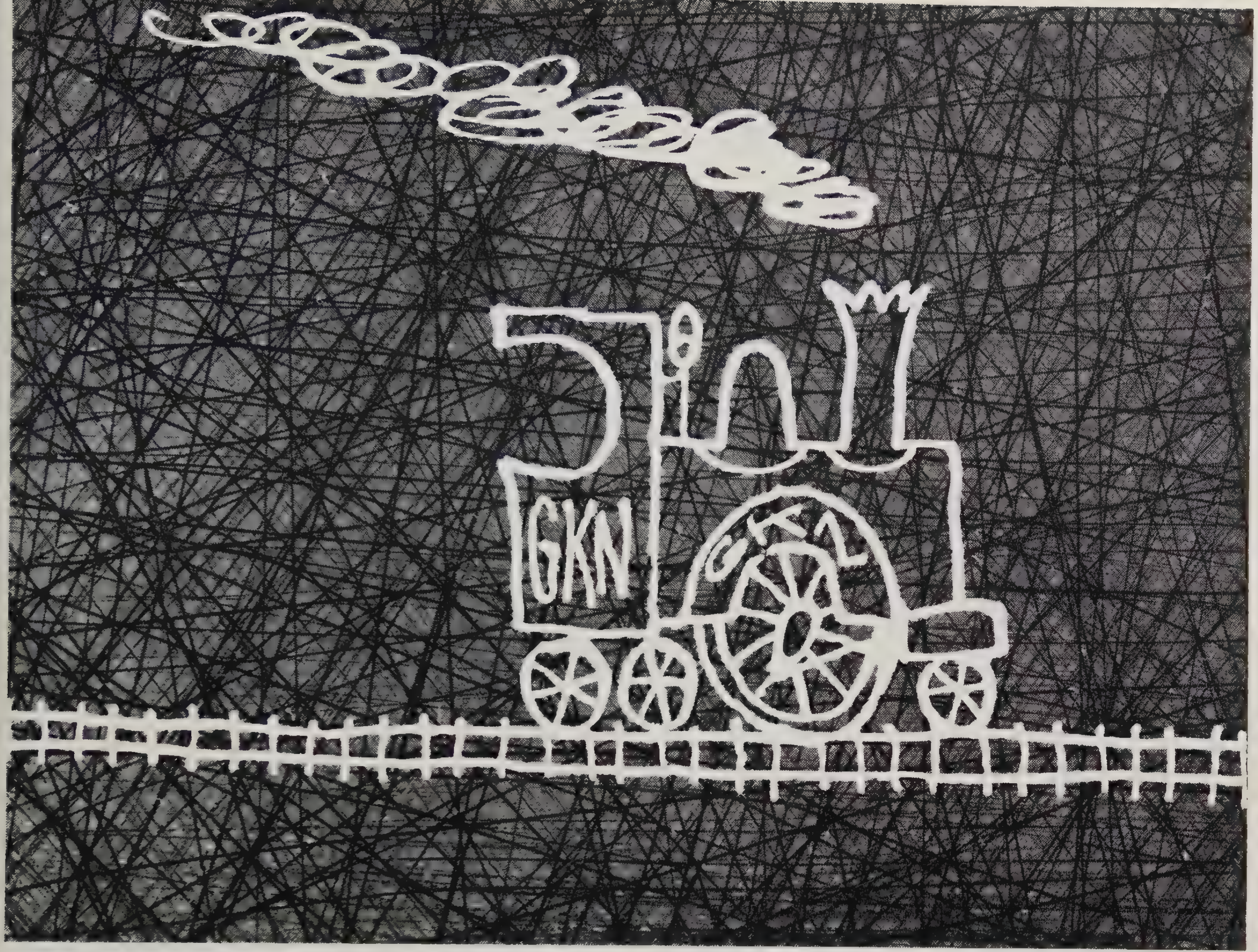
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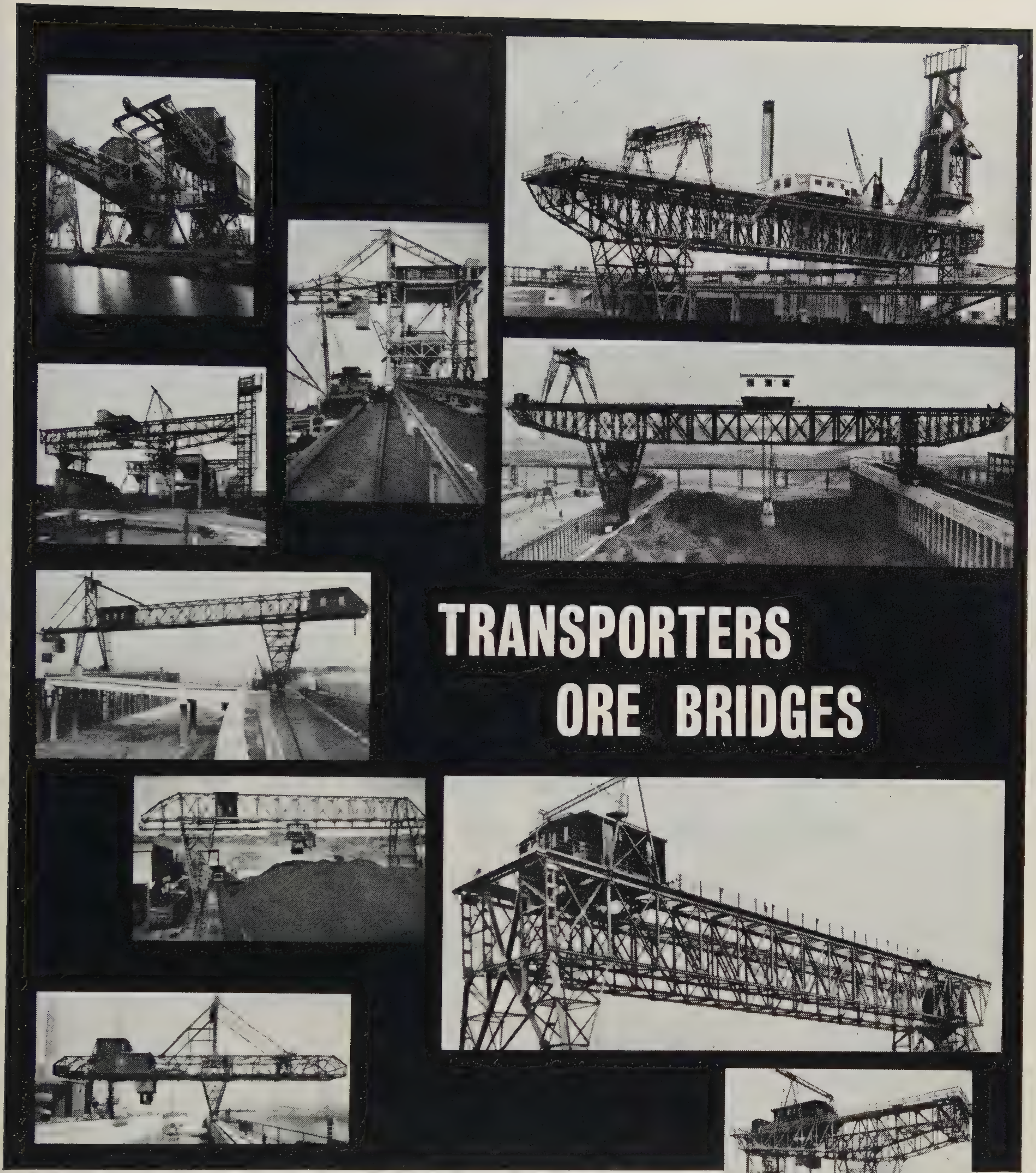

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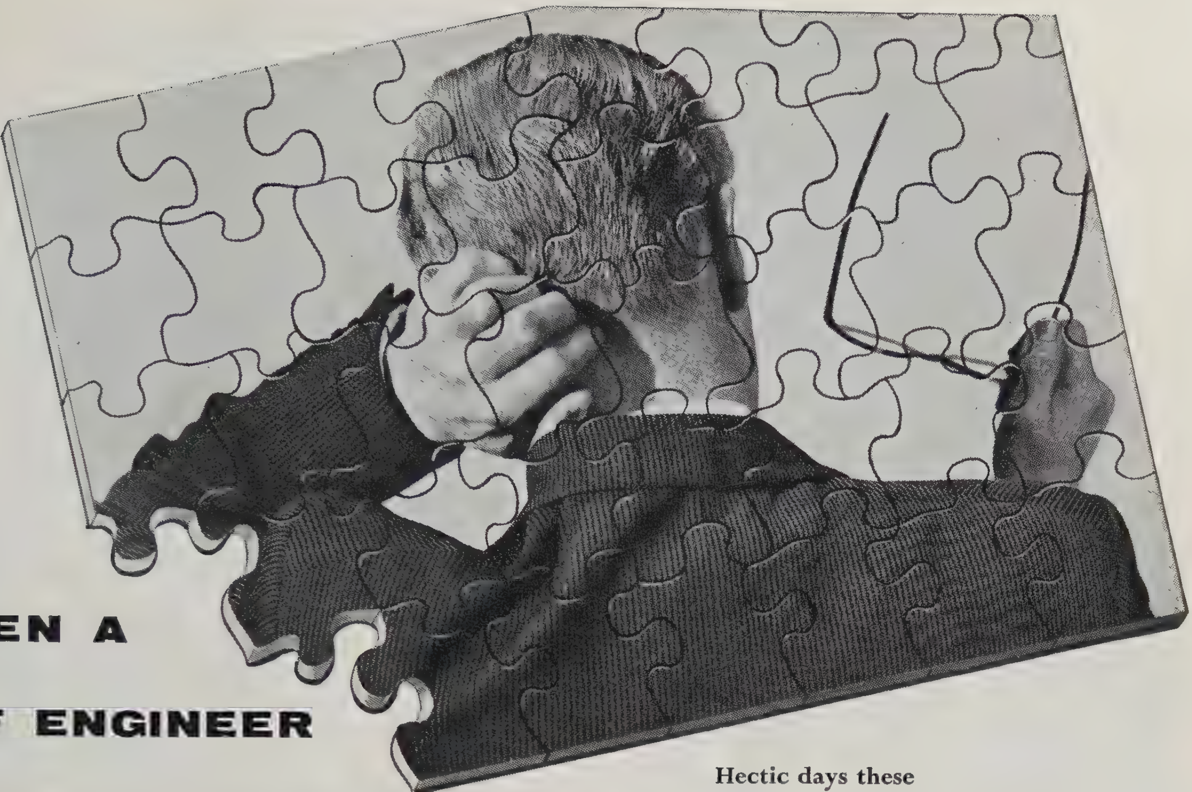

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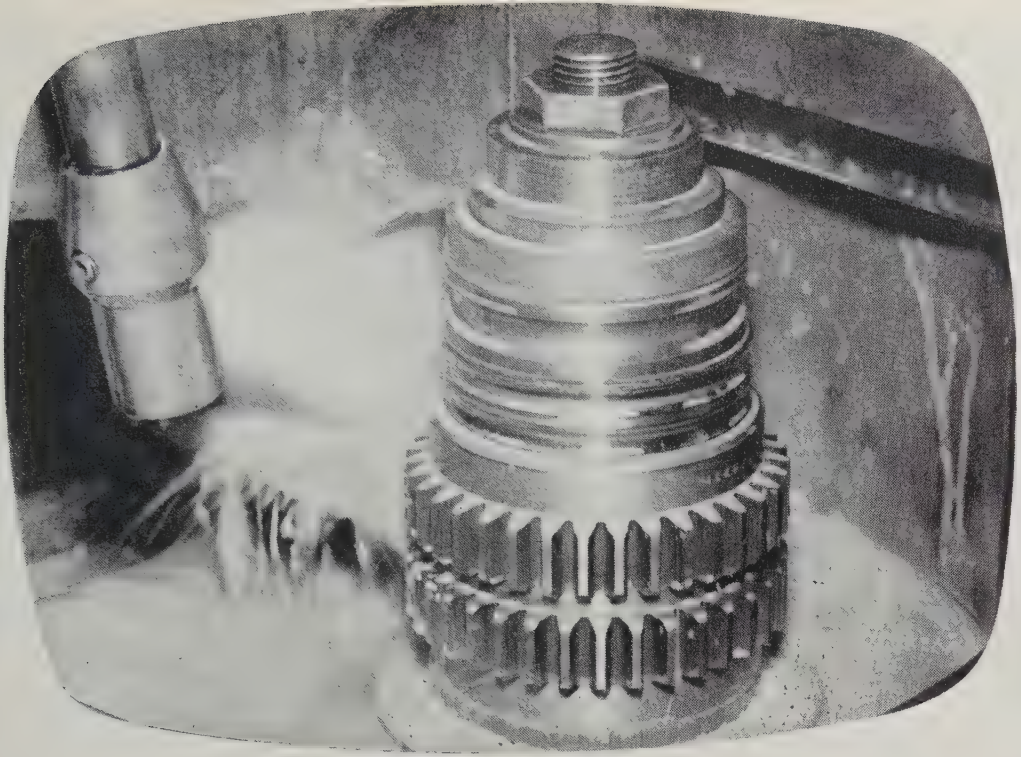

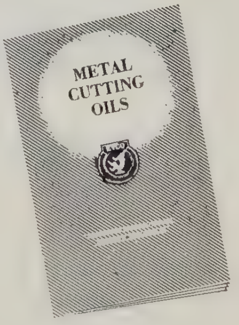
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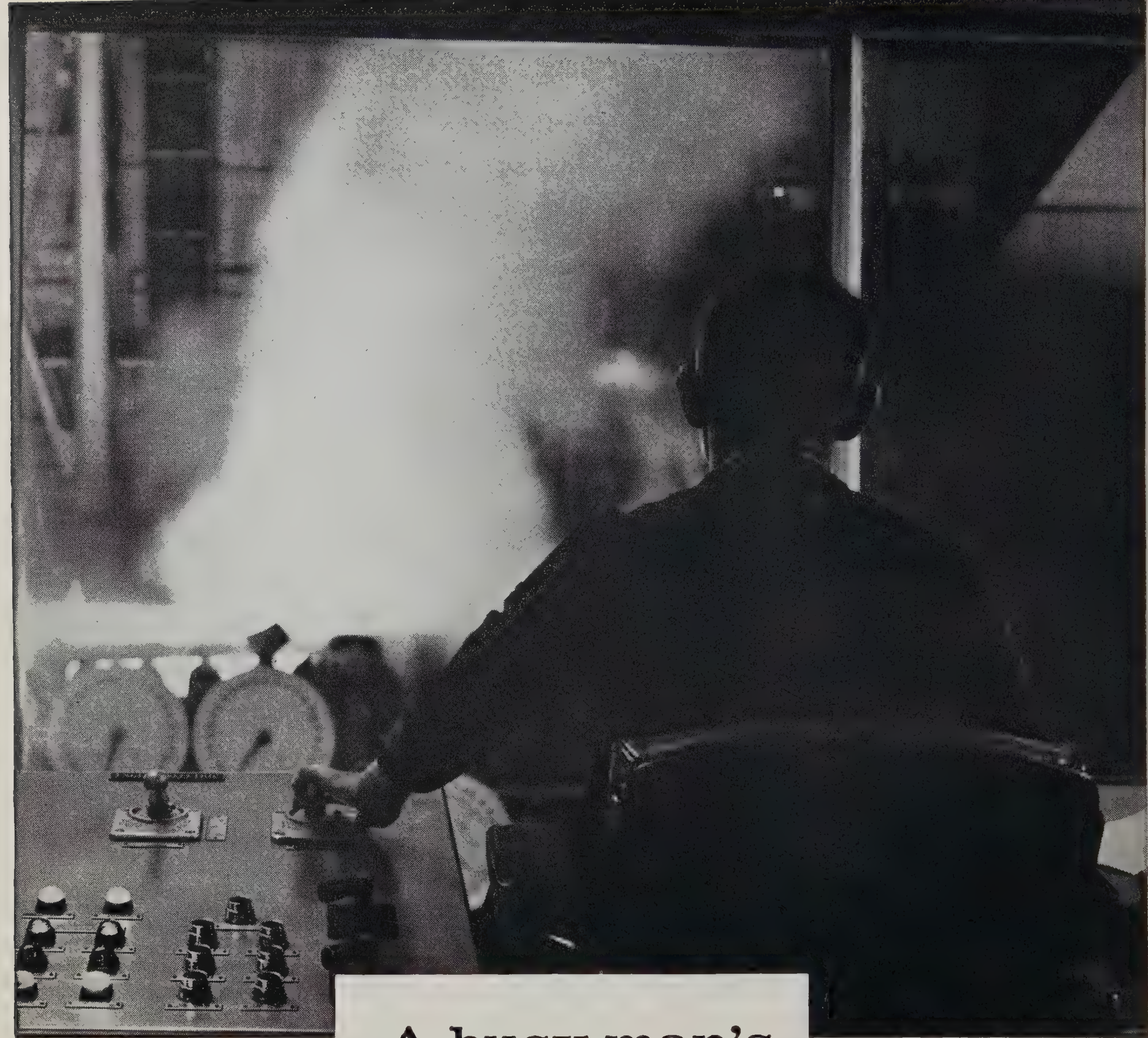
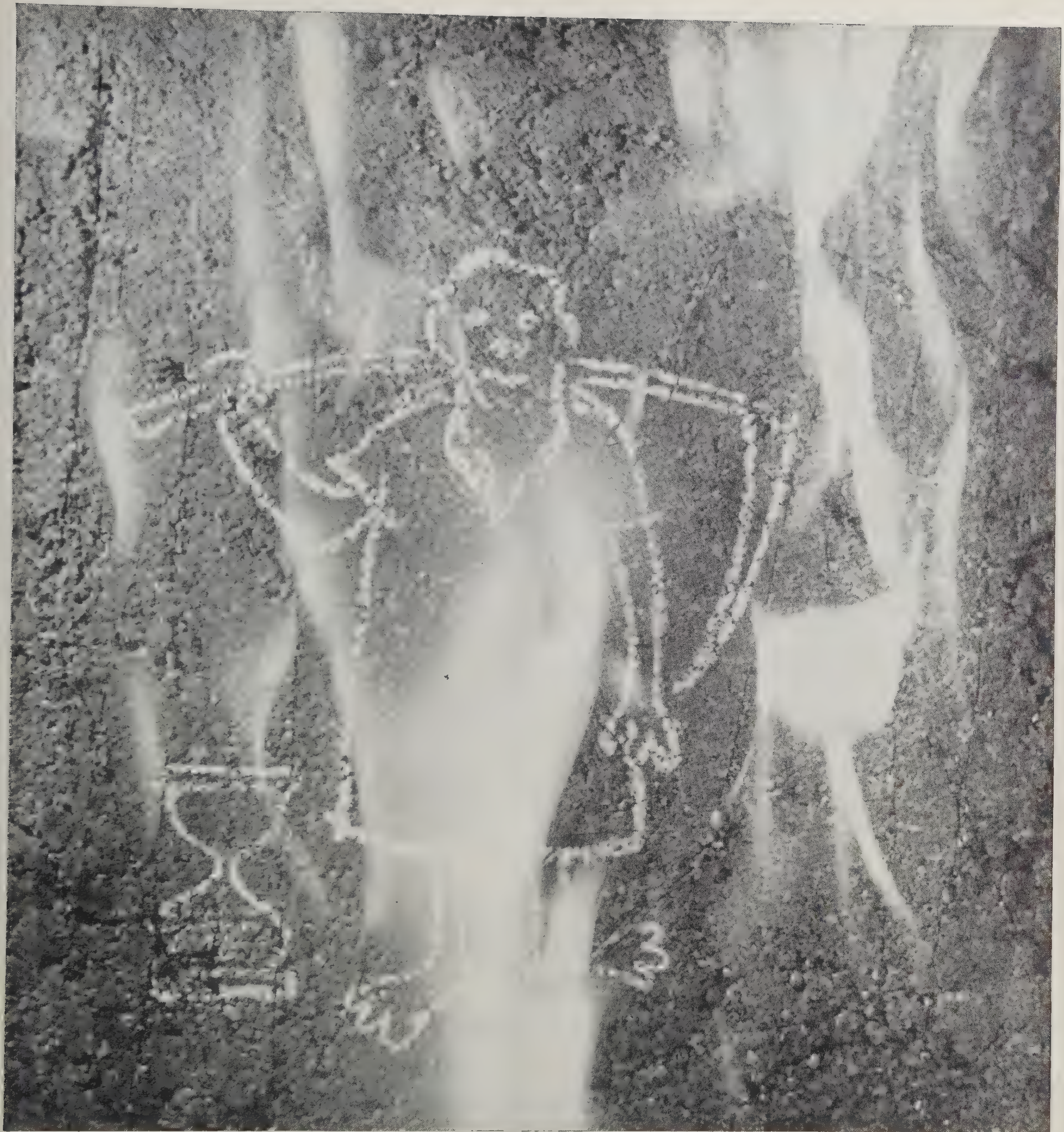
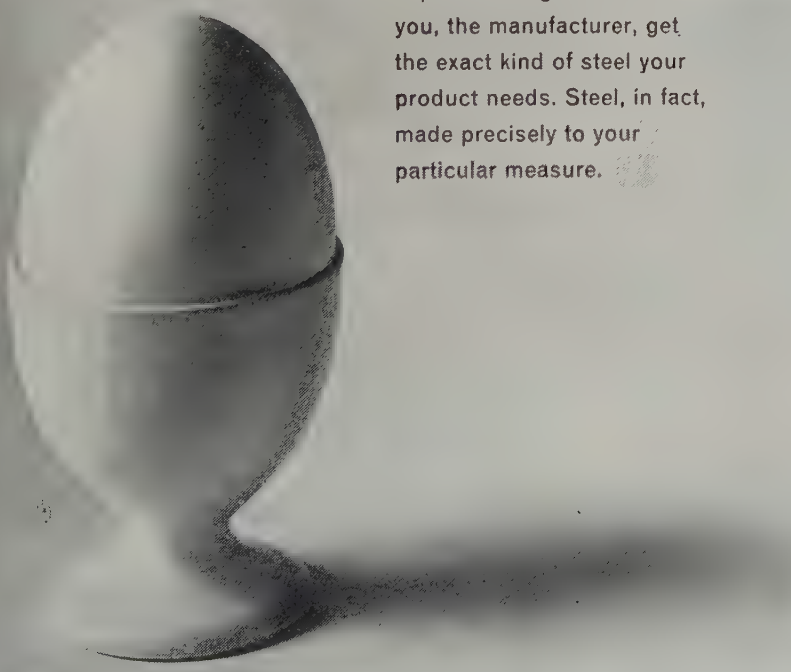
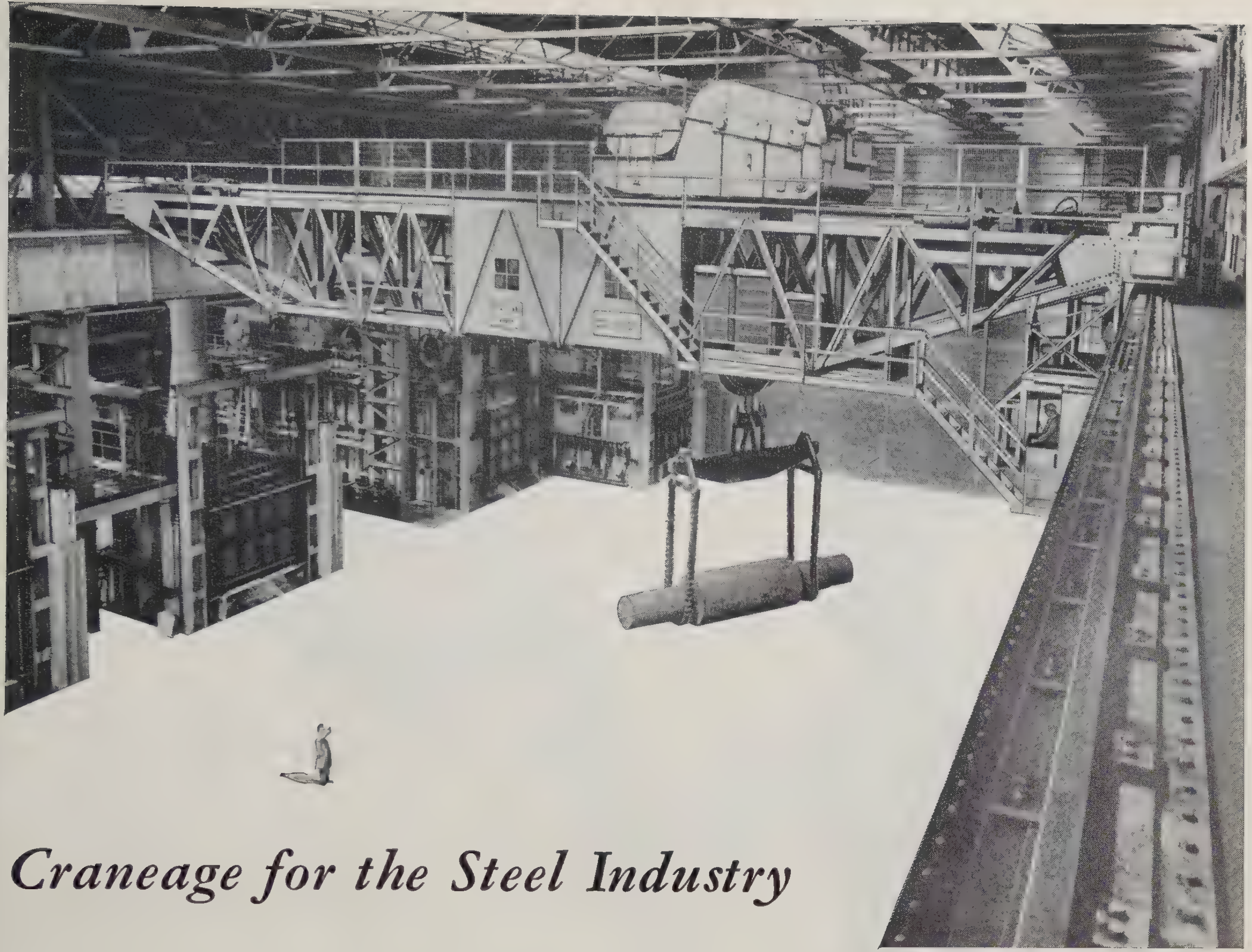






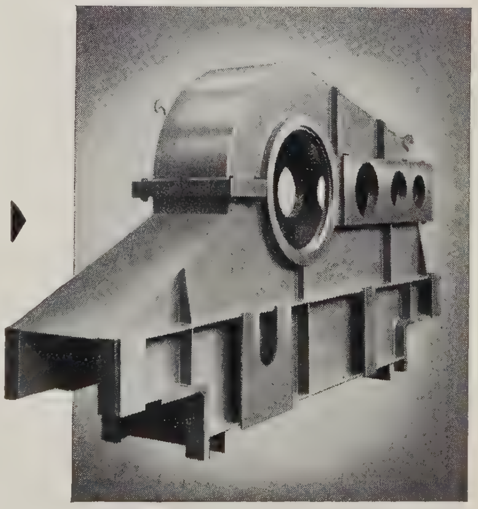


Craneage for the Steel Industry

Upper photograph by courtesy of Messrs. Thomas Firth & John Brown Ltd.

A 130/40 tons heavy duty electric overhead travelling crane handling forgings in the Bessemer Heat Treatment Department at Messrs. Thos. Firth & John Brown Ltd., Sheffield.

Fabricated steel gearboxes are a salient feature of Clyde-Booth practice. In this example the gearbox and crab side members form a monobloc box-section of great strength and rigidity.



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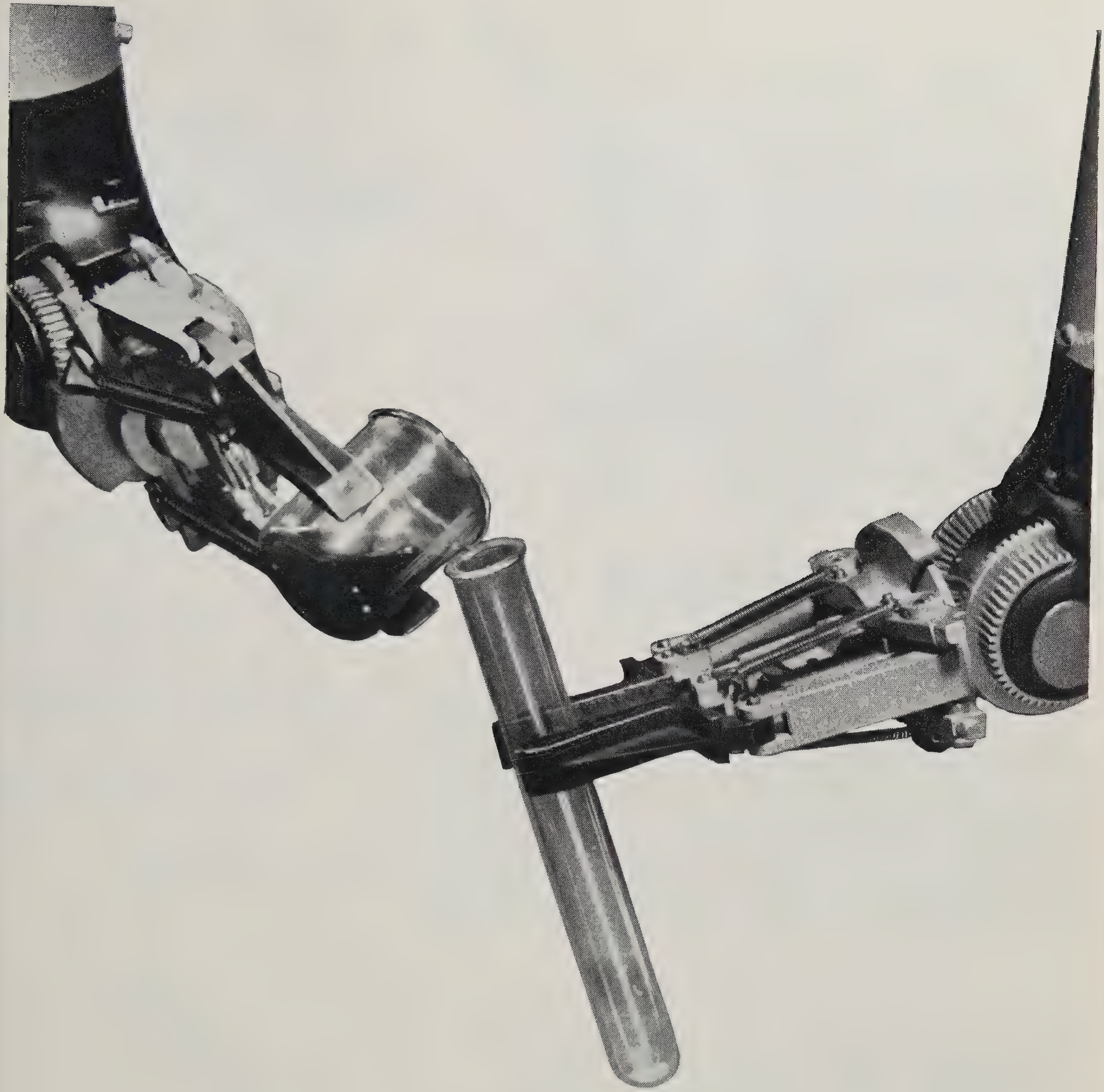

A symposium on steels for reactor pressure circuits, organized by The Iron and Steel Institute for the British Nuclear Energy Conference, took place in London at the end of last year. Sir Leonard Owen's introductory address, the 26 papers which were delivered, and the six related discussions, have now been published by the Institute as its Special Report 69

Steels for reactor pressure circuits

The papers and discussions are in five general groups: high-temperature properties, corrosion, fabrication aspects, irradiation effects, and steels for future reactors. The report ends with a general discussion.

In octavo format, with 587 pages of text and extensive illustrations in line and tone, the report costs 65*s*. (postage included) and is available from the Secretary of The Iron and Steel Institute, 4 Grosvenor Gardens, London SW1.

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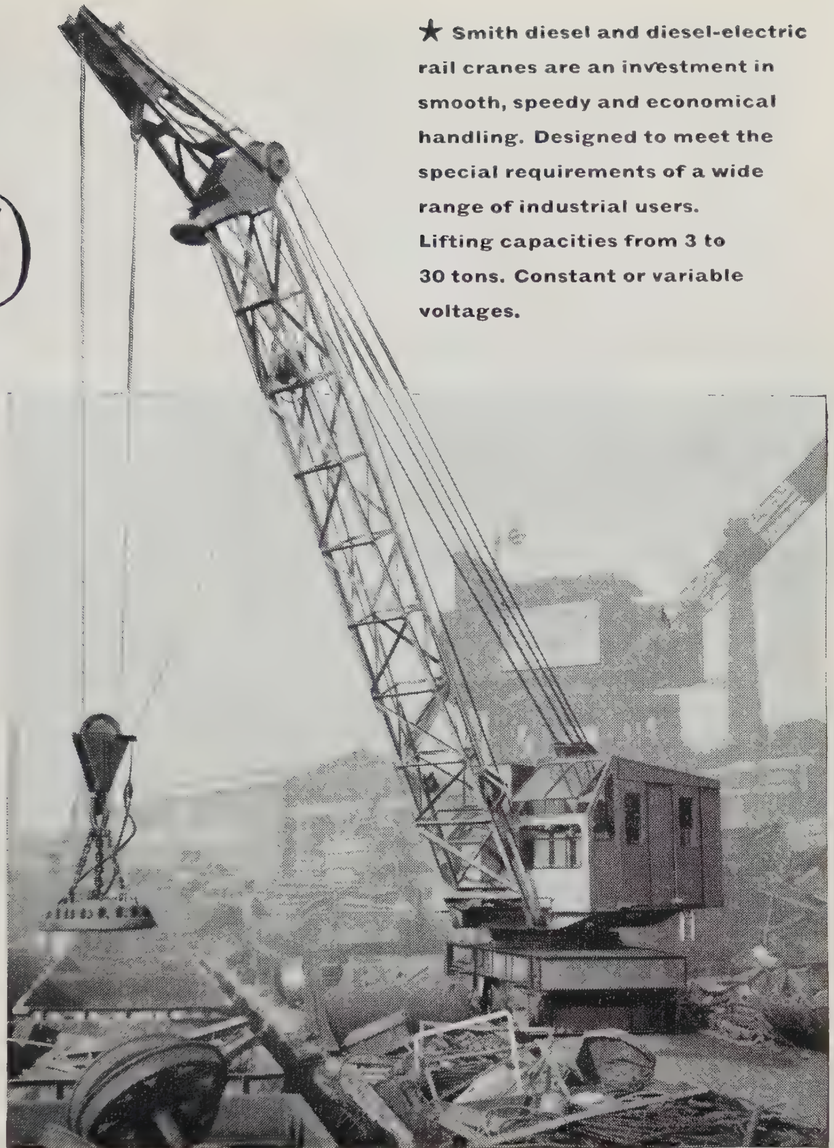

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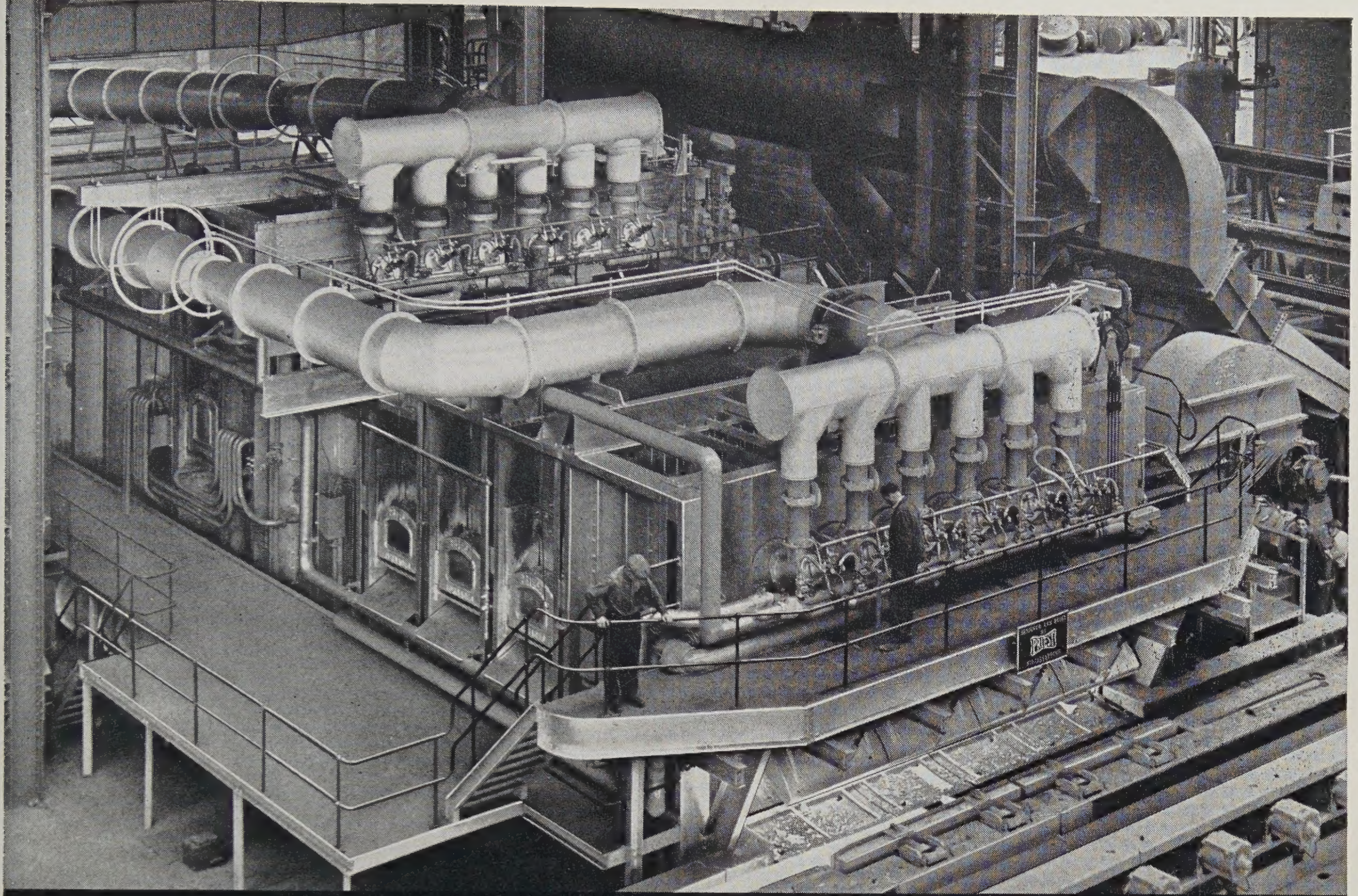

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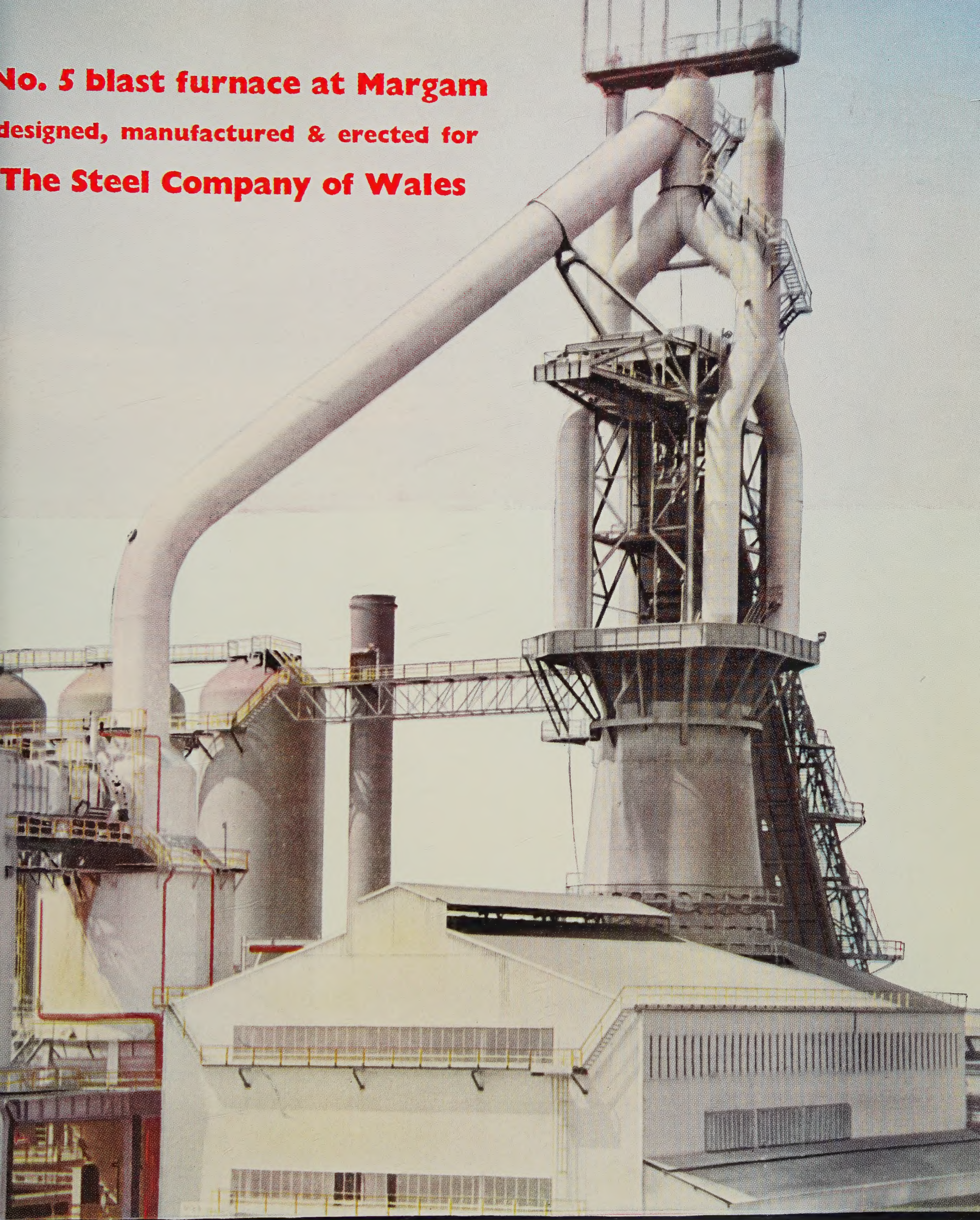
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